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Pitzer

(10) **Patent No.: US 9,480,202 B2**
(45) **Date of Patent: Nov. 1, 2016**

(54) **AUTOMATED SELECTIVE HARVESTING OF CROPS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2 days.

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(60) Provisional application No. 61/919,168, filed on Dec. 20, 2013.

(51) **Int. Cl.**
A01D 45/00 (2006.01)
A01D 46/30 (2006.01)

(52) **U.S. Cl.**
CPC ***A01D 46/30*** (2013.01); *A01D 45/006* (2013.01)

(58) **Field of Classification Search**
CPC A01D 45/00; A01D 45/007; A01D 46/00; A01D 46/247; A01D 45/006; A01D 46/30; Y10S 56/08
USPC 56/1, 327.1, 327.2; 171/8, 39, 47, 56; 294/111
See application file for complete search history.

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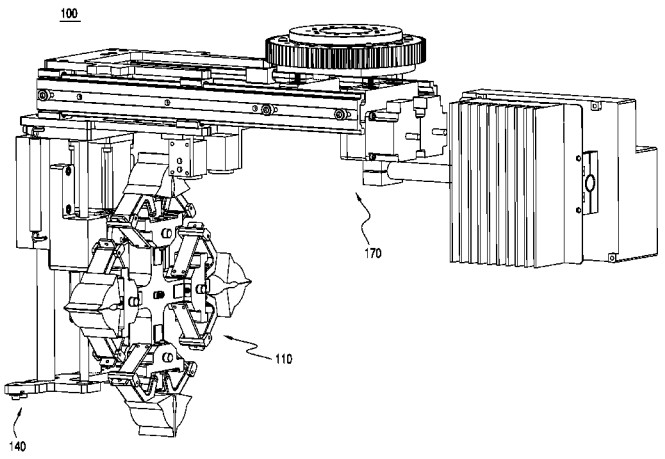
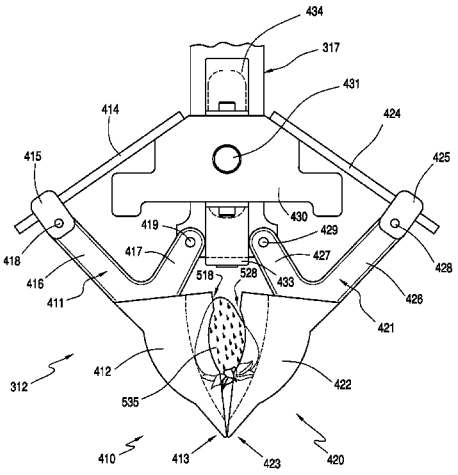
(57) **ABSTRACT**

Various embodiments include a device for selectively harvesting crops on a plant. The device can include a picking apparatus. The picking apparatus can be rotatable around a central axis. The picking apparatus can include a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops. Each of the plurality of grippers can be adjustable between an open position and a closed position. Each of the plurality of grippers can be configured in the open position to open around the individual crop. Each of the plurality of grippers can be configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis. Other embodiments are provided.

25 Claims, 19 Drawing Sheets





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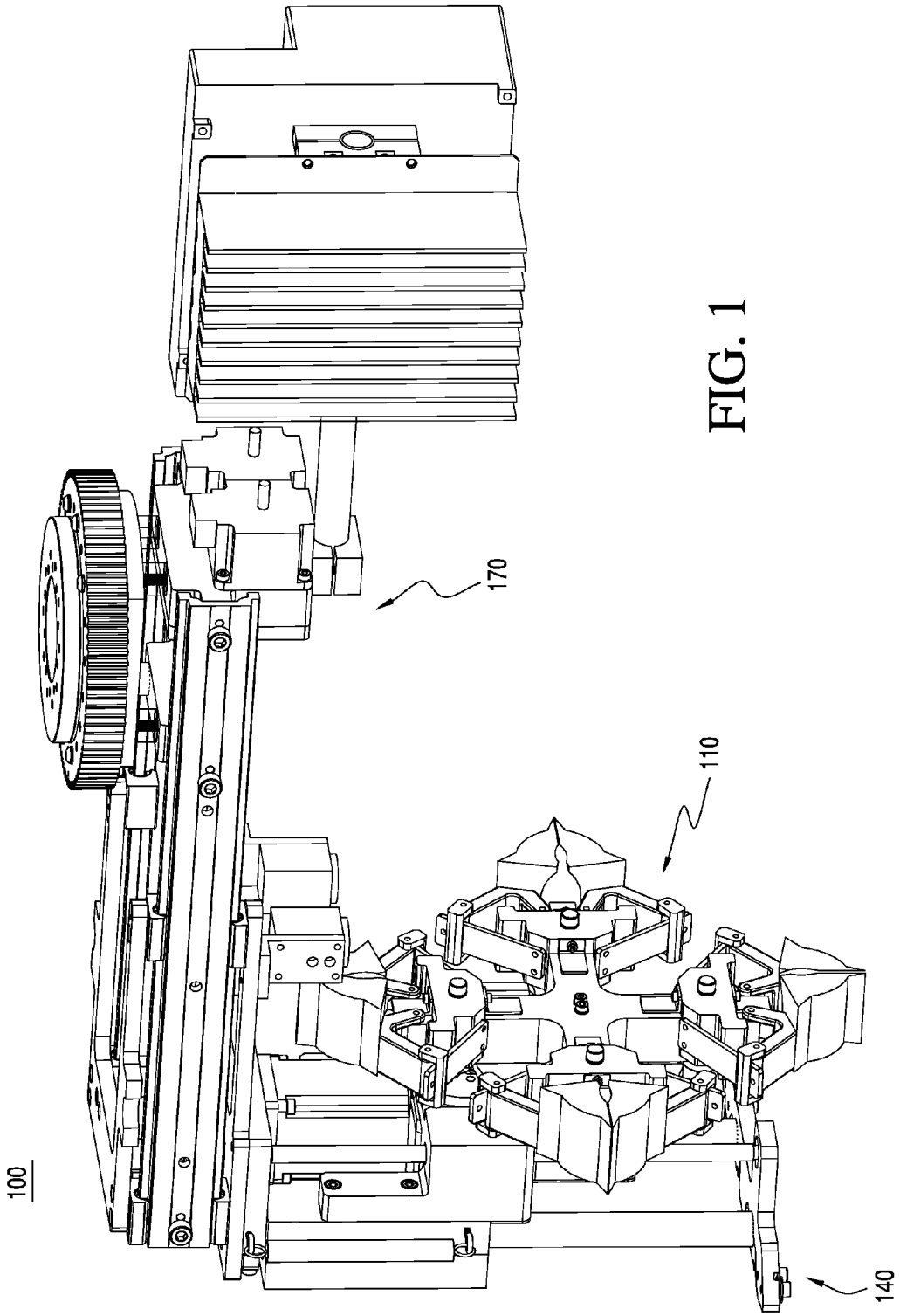


FIG. 1

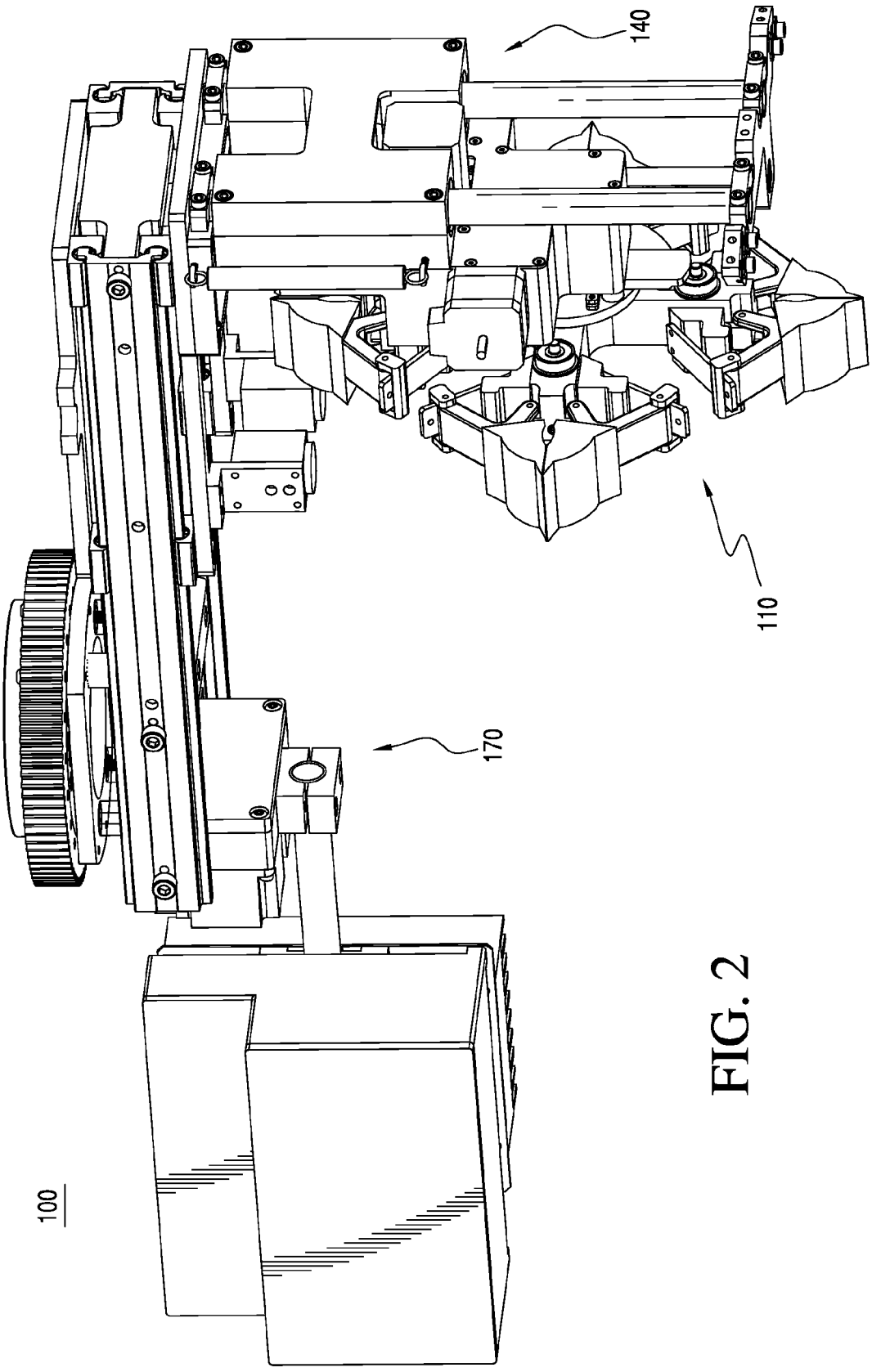
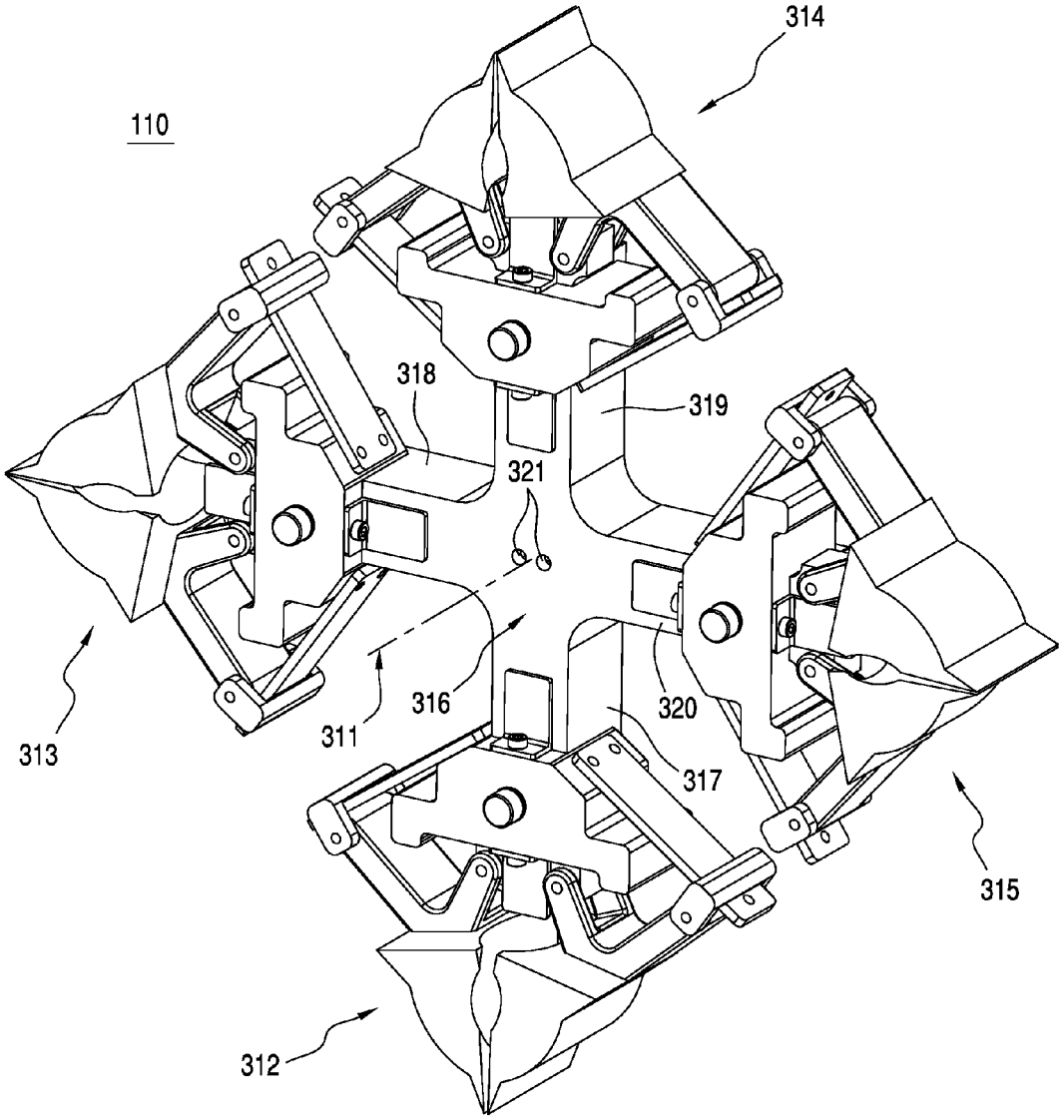


FIG. 2



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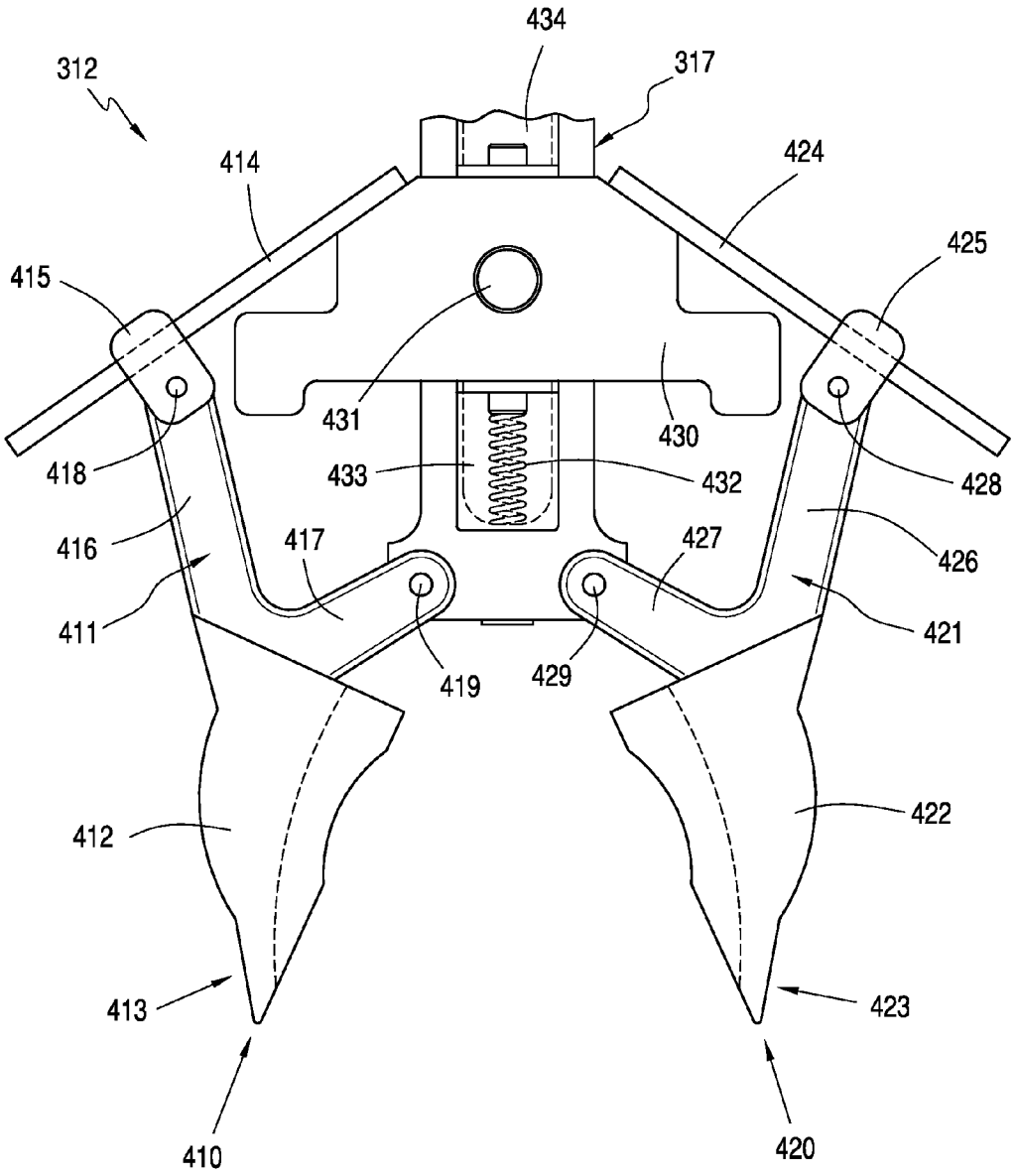
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FIG. 4

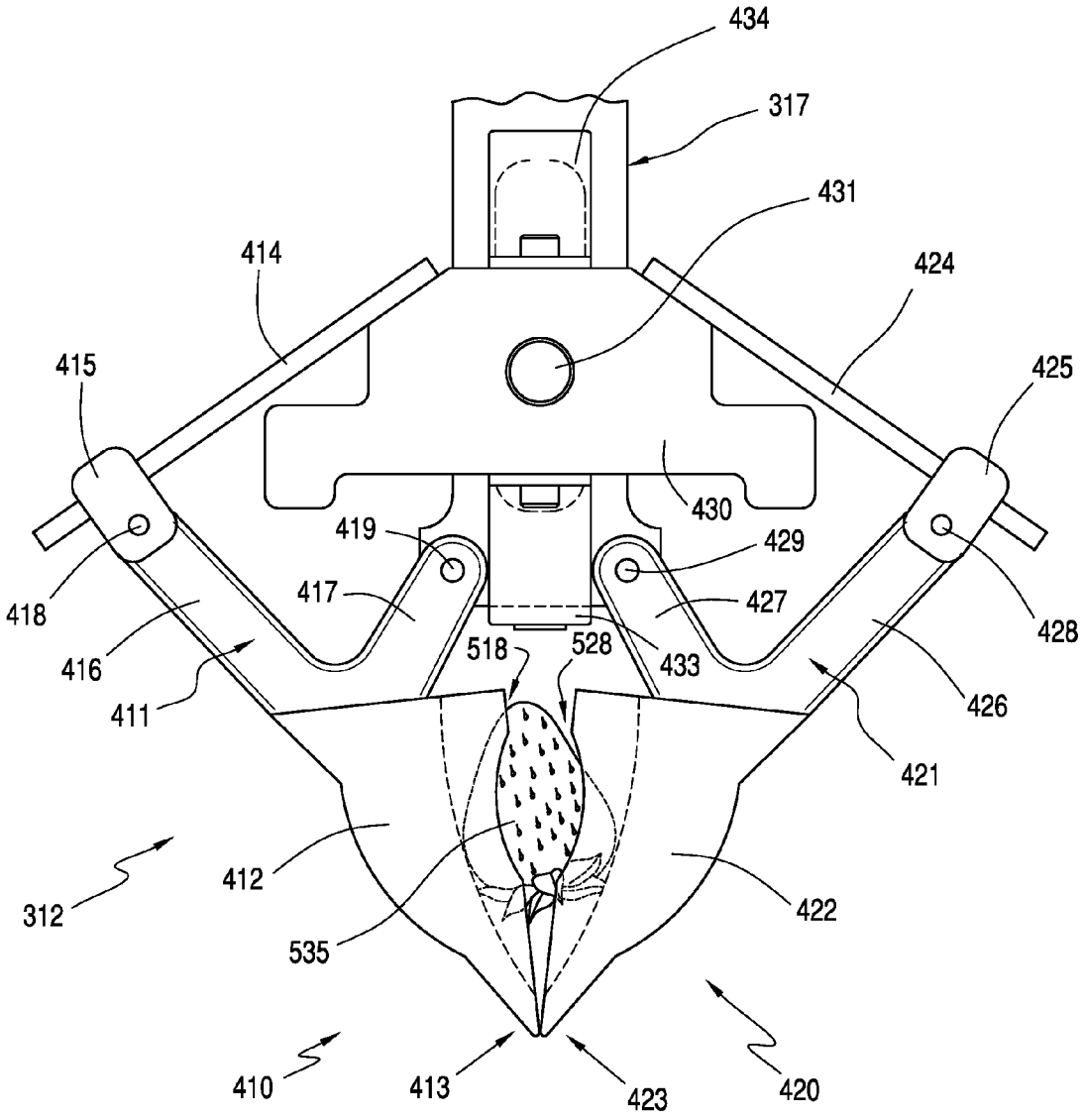
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FIG. 5

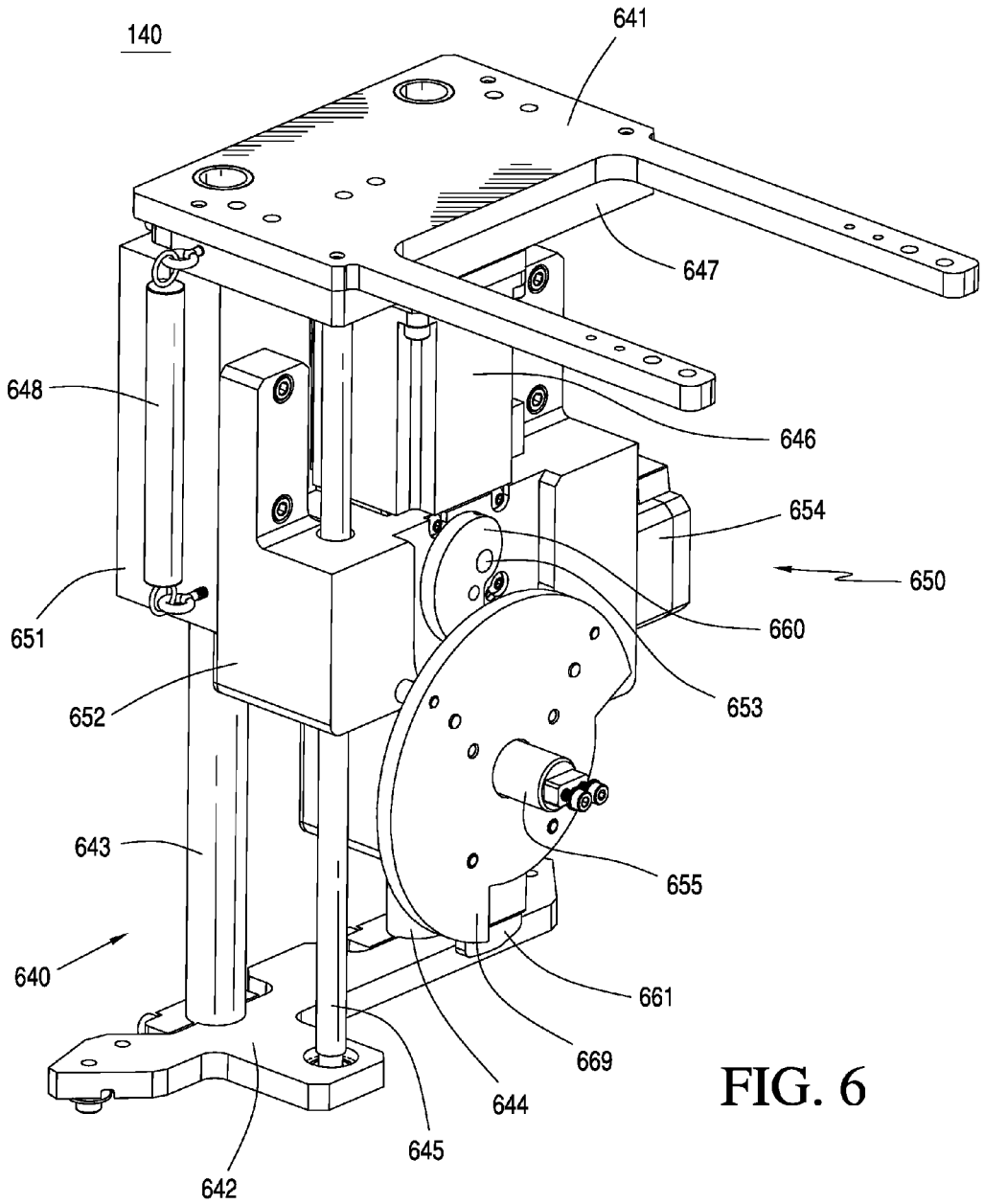
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FIG. 6

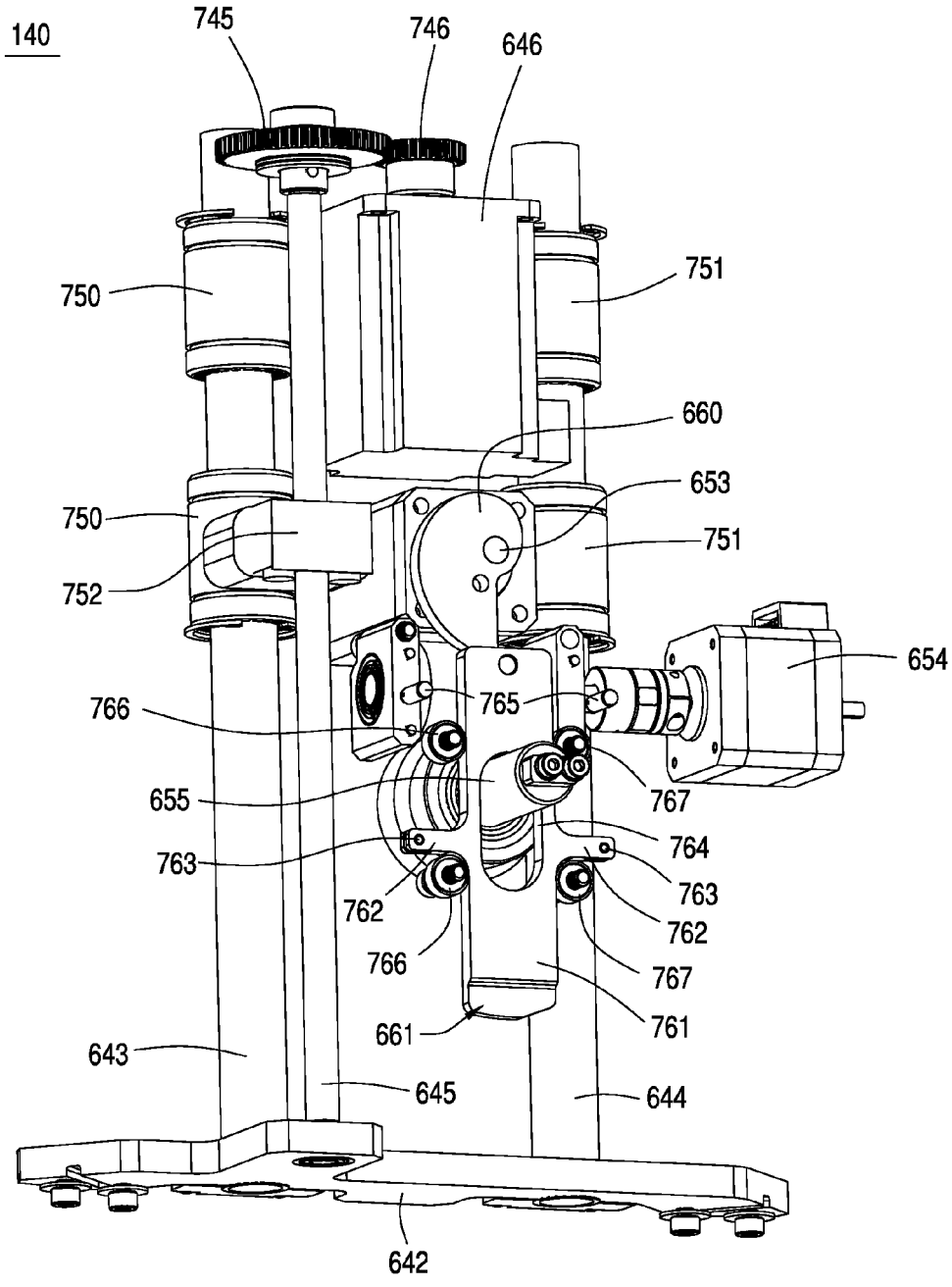
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FIG. 7

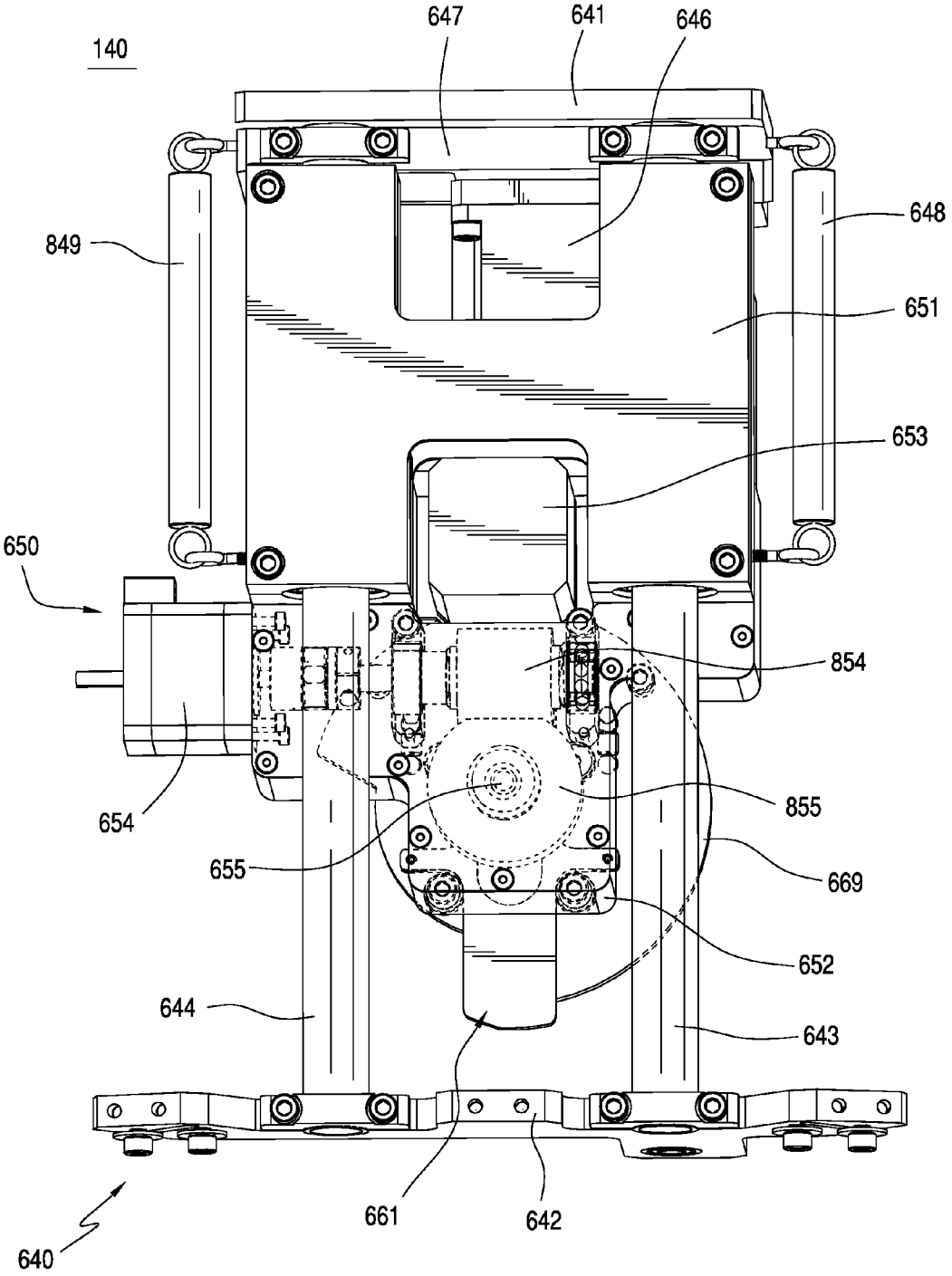
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FIG. 8

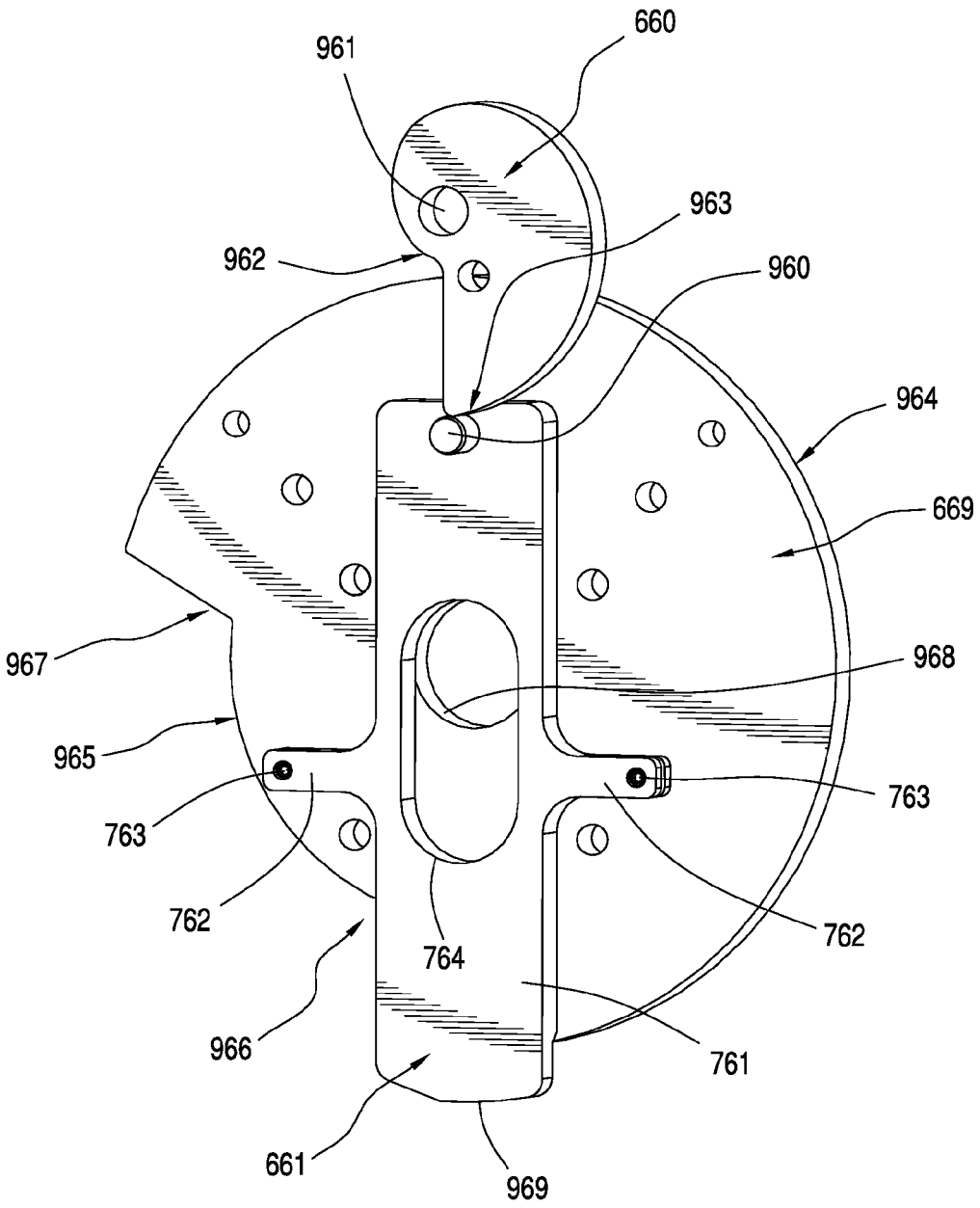
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FIG. 9

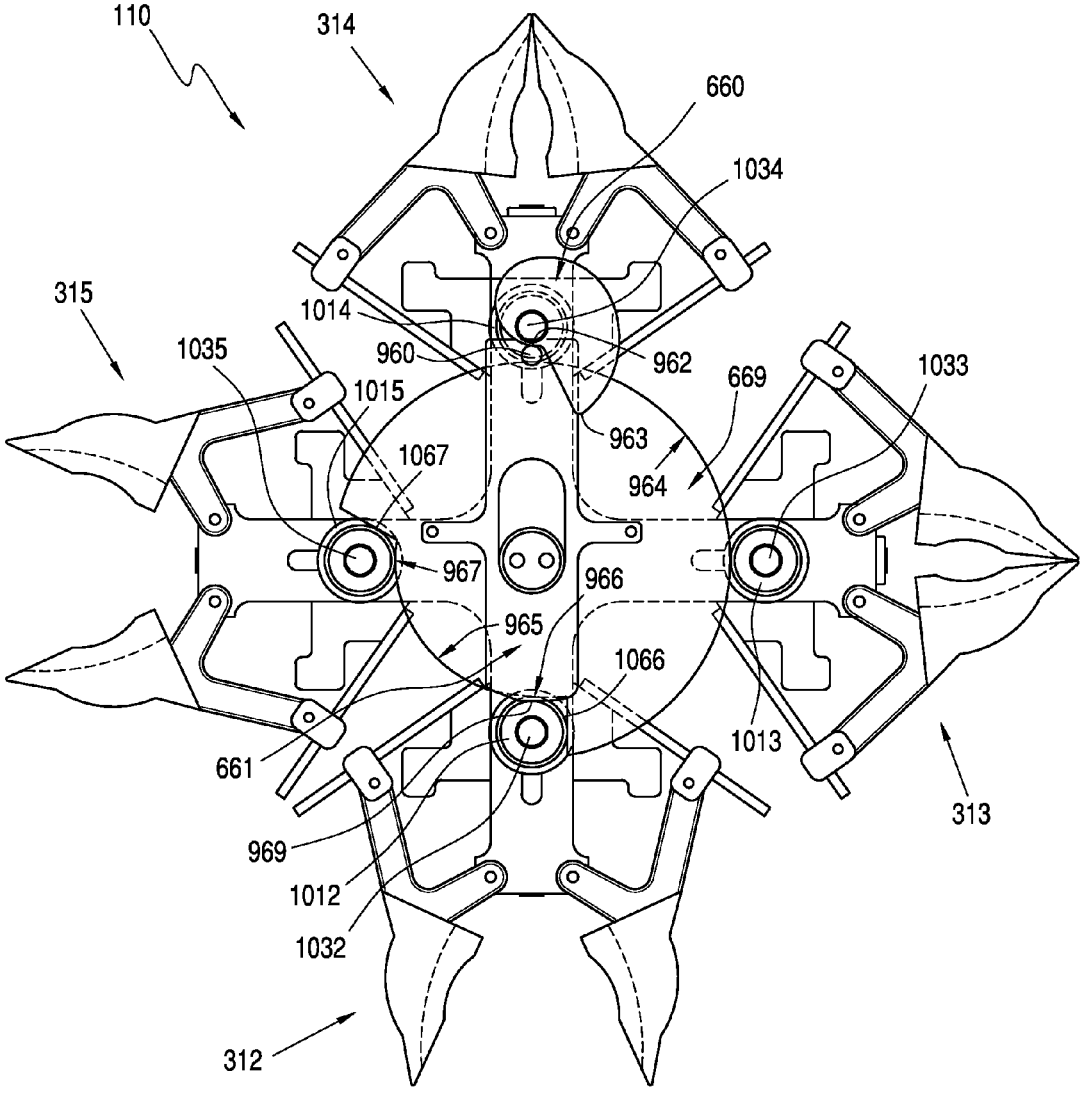
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FIG. 10

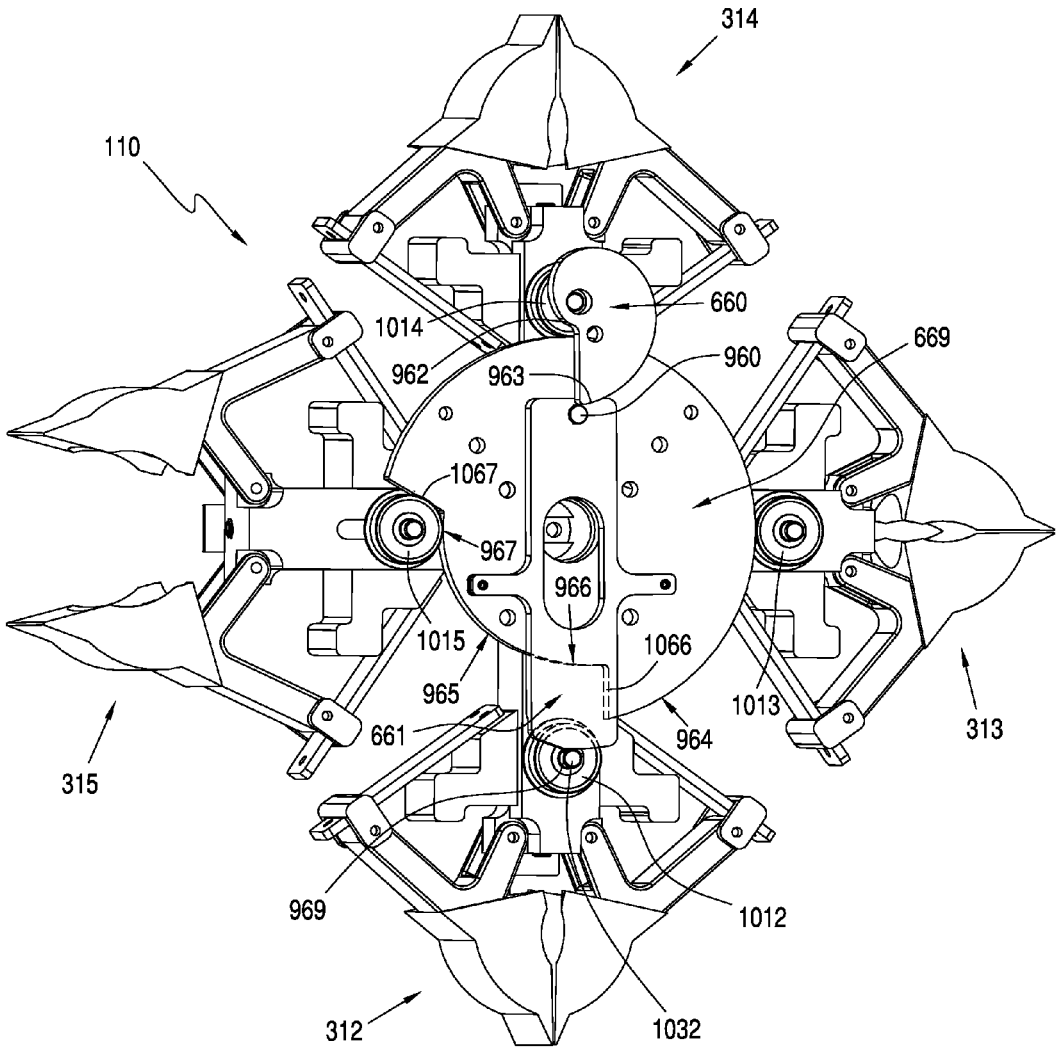
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FIG. 11

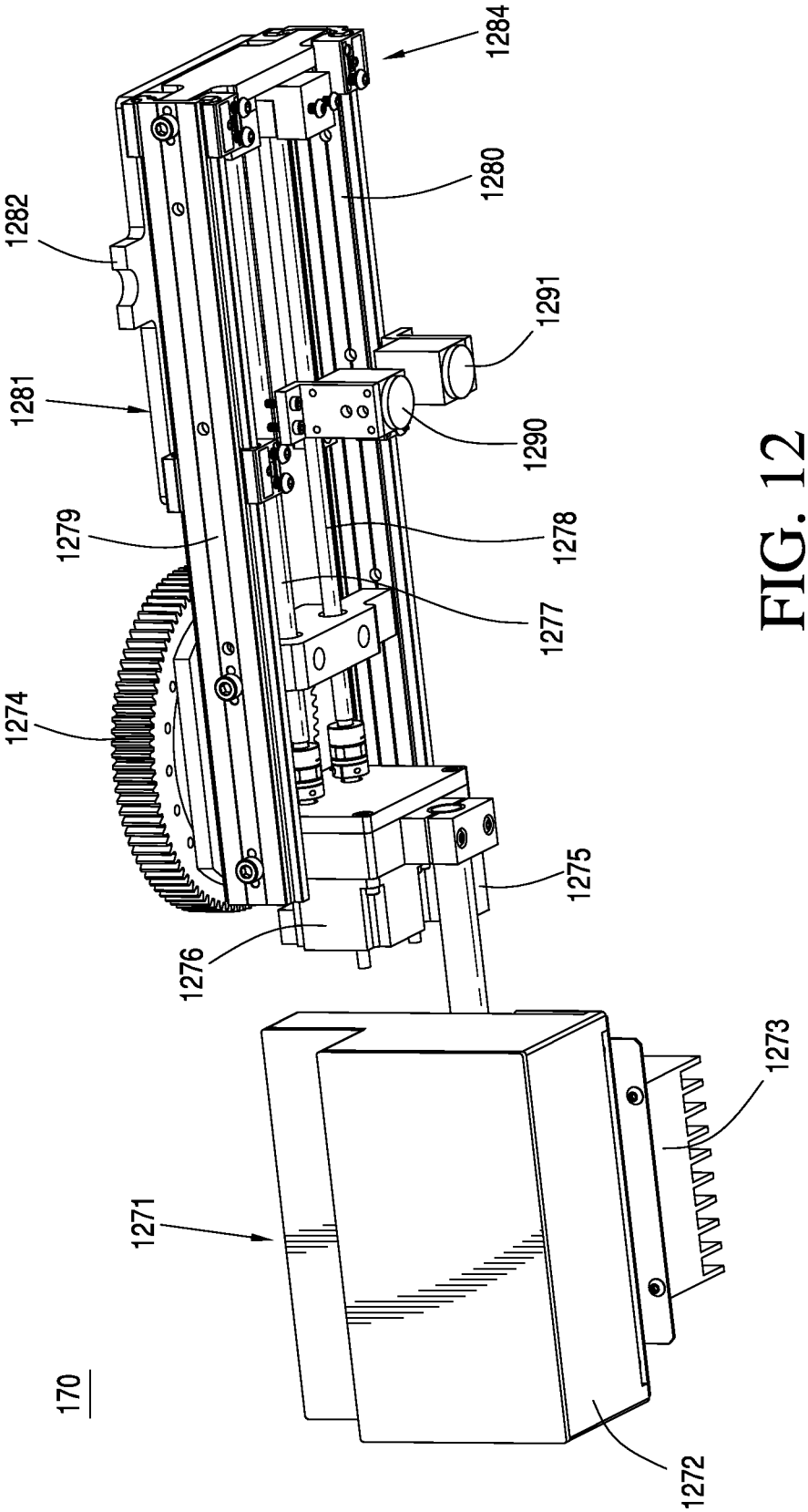
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FIG. 12

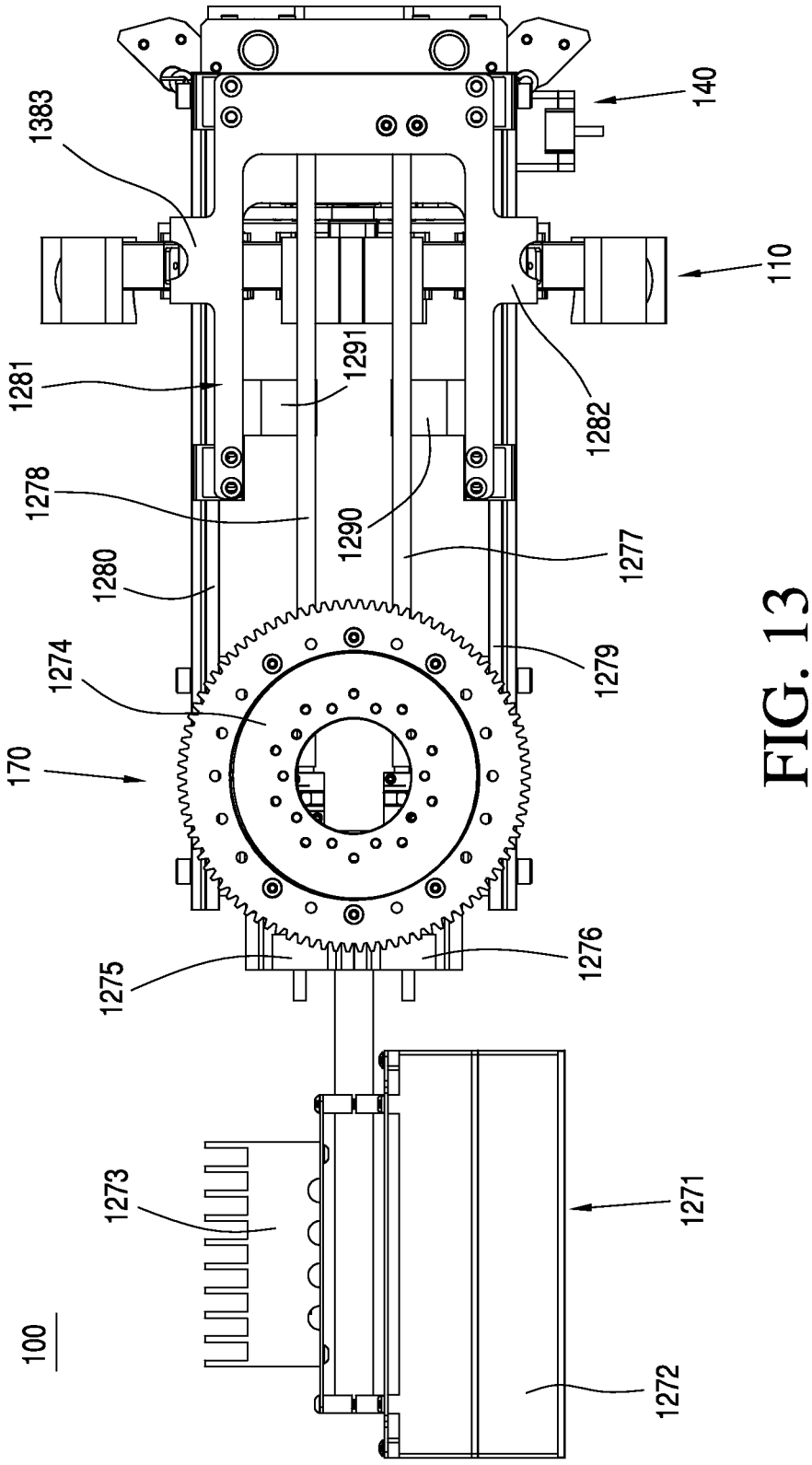
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FIG. 13

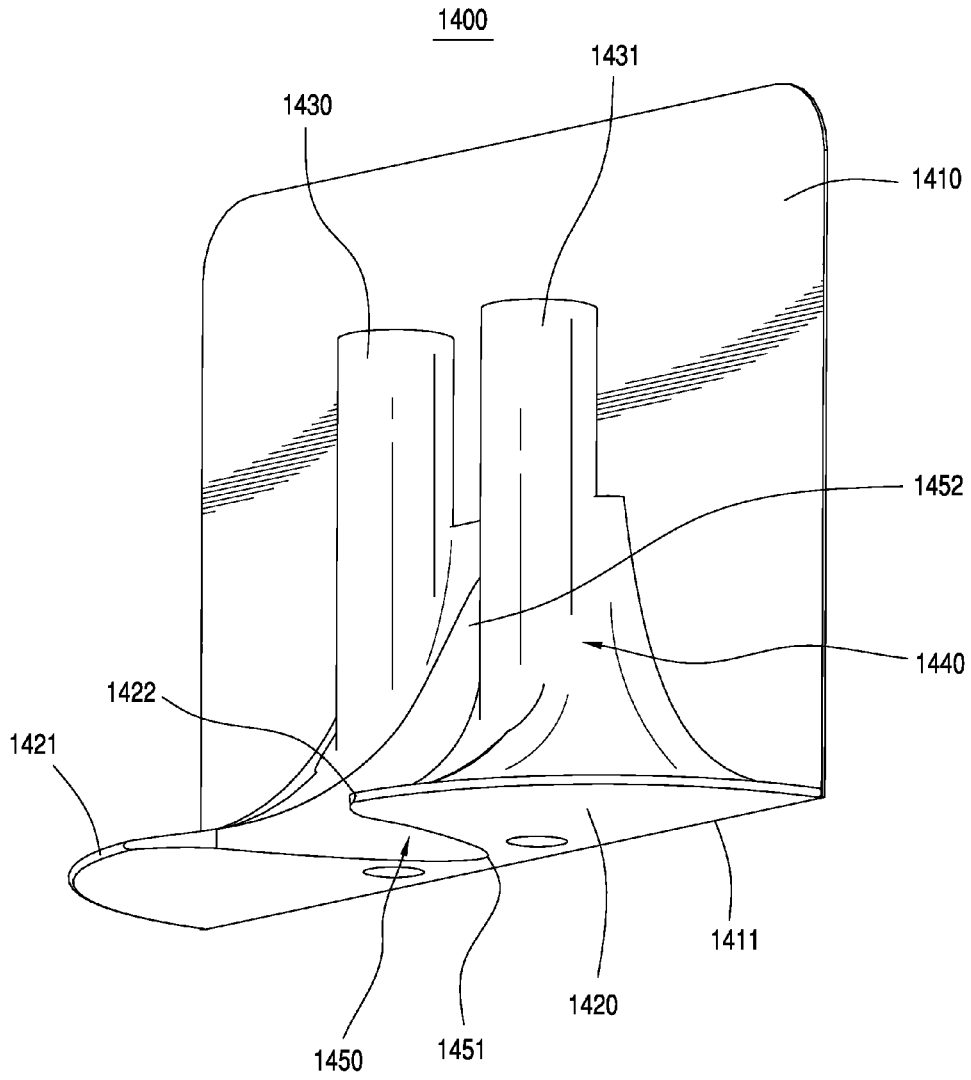

FIG. 14

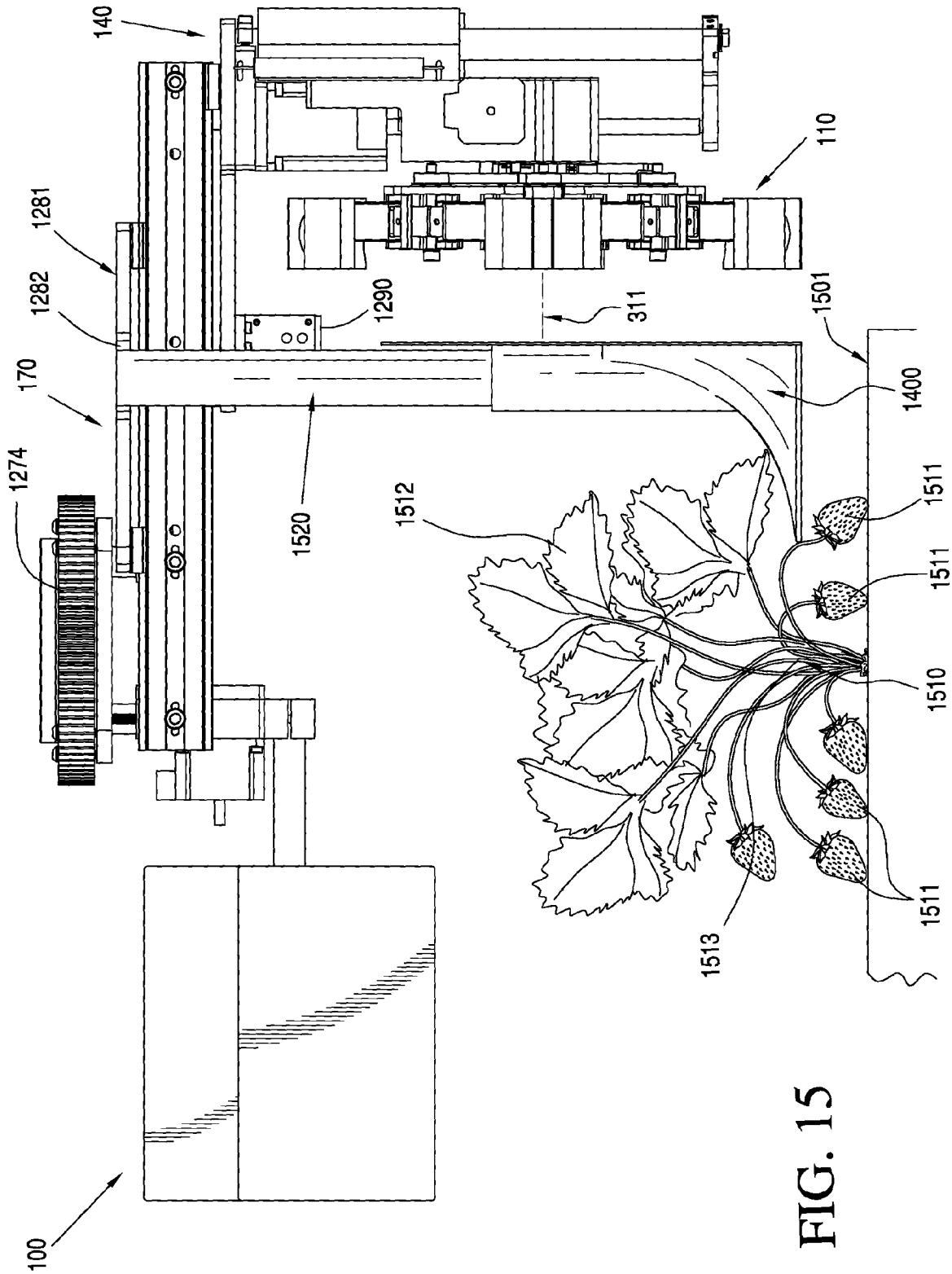
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FIG. 15

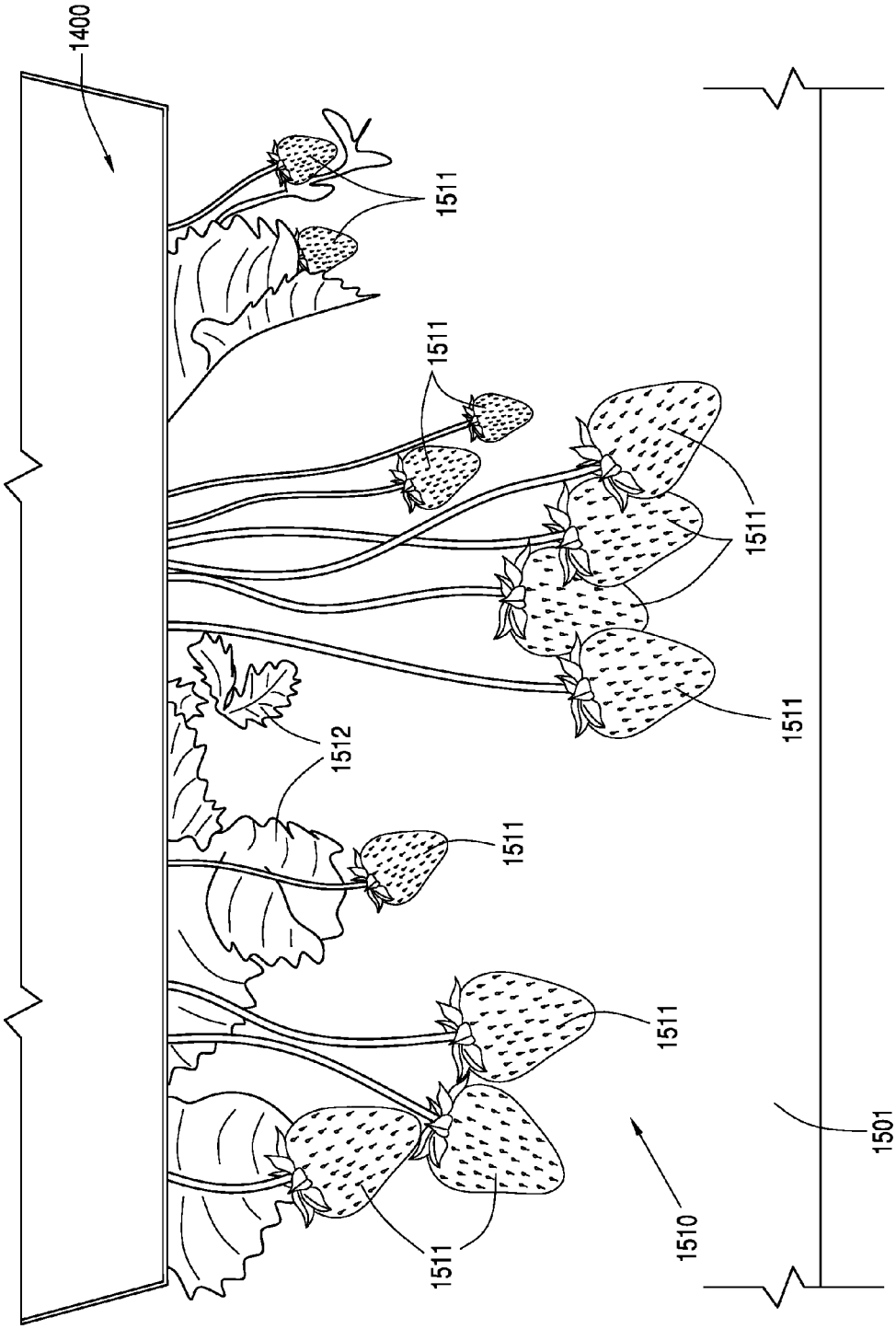


FIG. 16

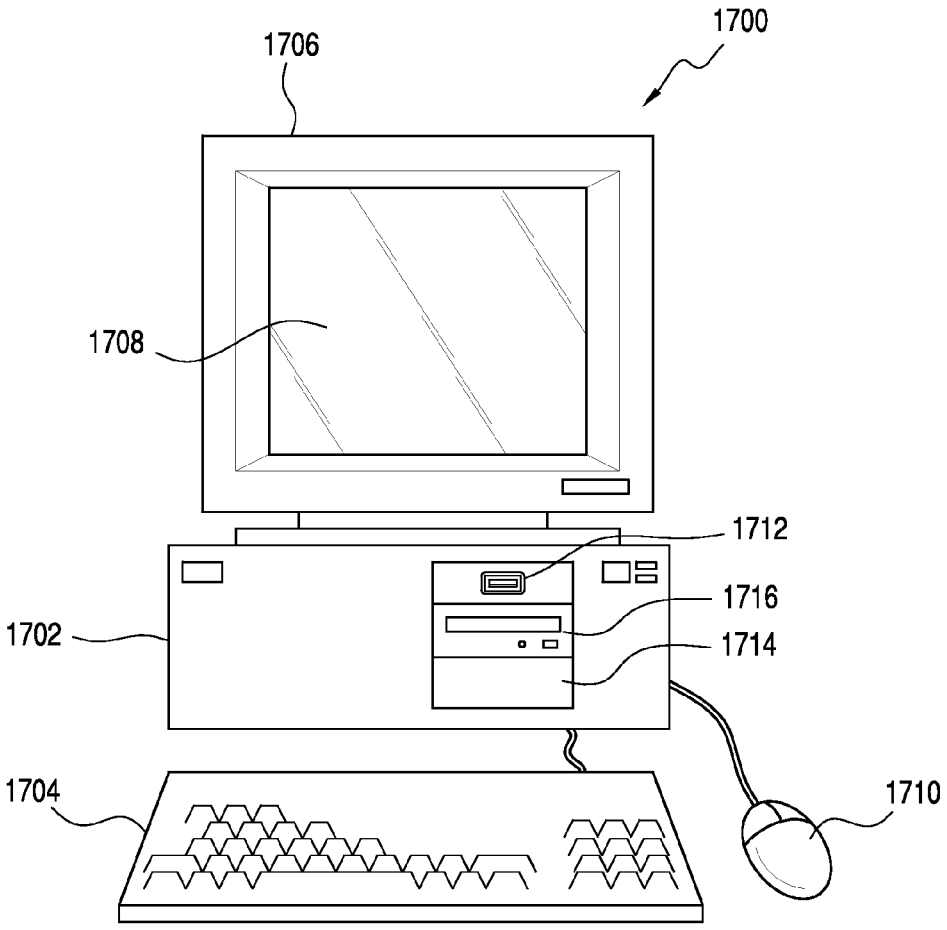
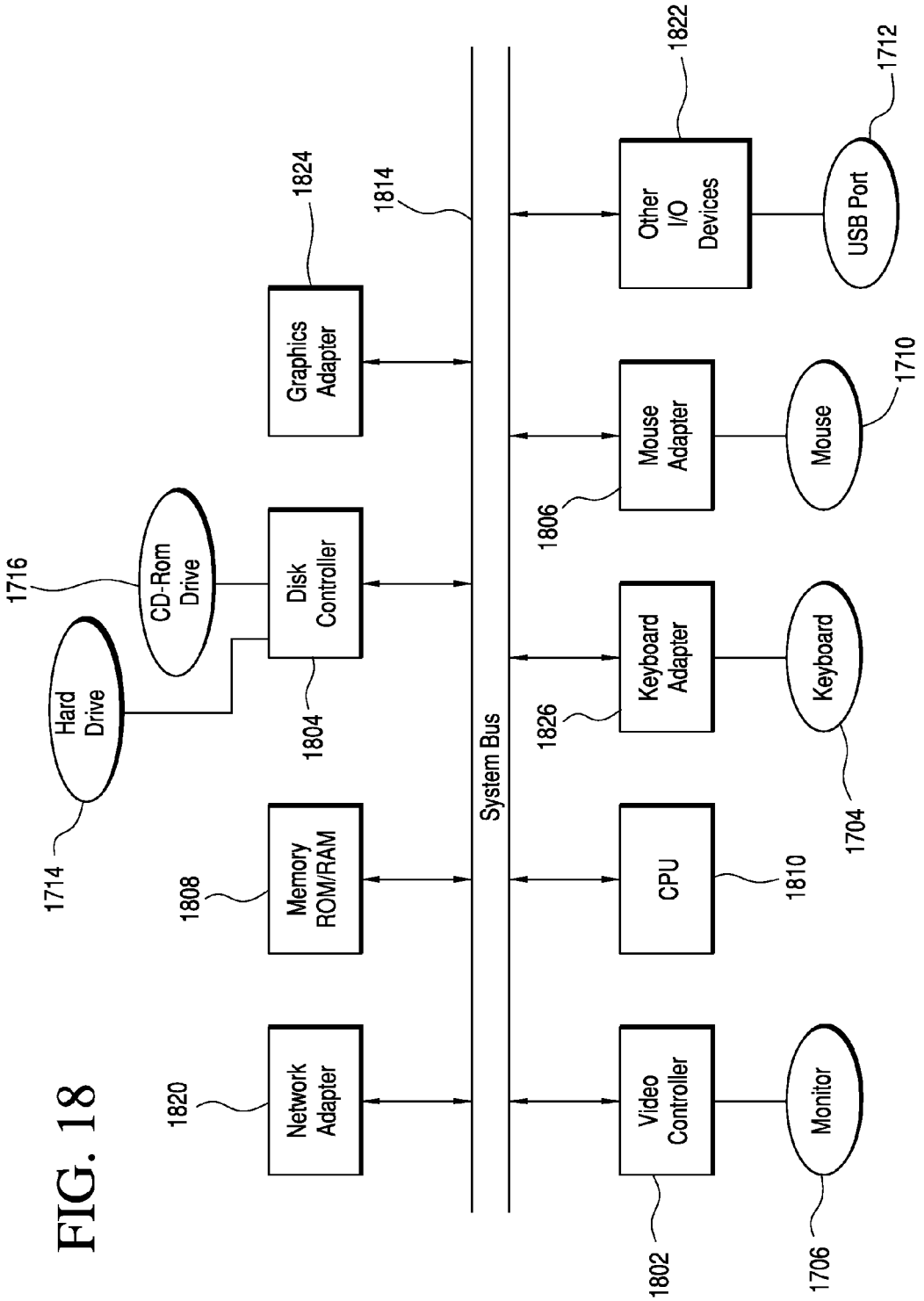


FIG. 17

FIG. 18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1808
Disk Controller
1804
Graphics Adapter
1824
CPU
1810
Keyboard Adapter
1826
Mouse Adapter
1806
Other I/O Devices
1822
Video Controller
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Mouse
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USB Port
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Hard Drive
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CD-Rom Drive
1716
1814

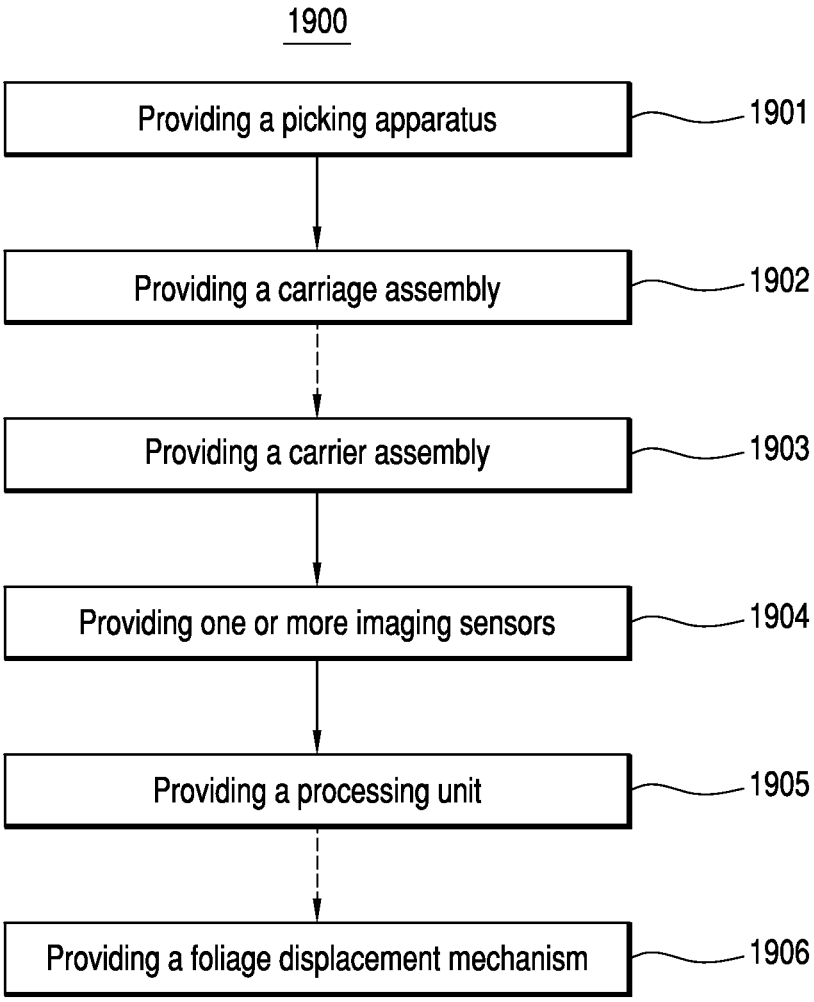
1900
Providing a picking apparatus
1901
Providing a carriage assembly
1902
Providing a carrier assembly
1903
Providing one or more imaging sensors
1904
Providing a processing unit
1905
Providing a foliage displacement mechanism
1906

FIG. 19

AUTOMATED SELECTIVE HARVESTING OF CROPS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/919,168, filed Dec. 20, 2013. U.S. Provisional Application No. 61/919,168 is incorporated herein by reference in its entirety.

TECHNICAL FIELD

This disclosure relates generally to crop harvesting, and relates more particularly to automated systems for selectively picking crops from plants.

BACKGROUND

Various crops, such as strawberries, have been harvested typically using manual labor due to the delicate nature of the crops and the selective nature of the harvesting. For example, laborers perform the harvesting by selectively picking ripe crops from the plants while leaving unripe crops on the plants for later harvesting when they have ripened. The high seasonal demand for laborers and the limited labor force has resulted in increased labor costs and crops being left unpicked. Further, labor shortages have resulted in portions of fields being left unplanted in order to avoid the effort, expense, and waste involved with growing unpicked crops.

BRIEF DESCRIPTION OF THE DRAWINGS

To facilitate further description of the embodiments, the following drawings are provided in which:

FIG. **1** illustrates a top, front, left side perspective view of a harvesting robot, according to an embodiment;

FIG. **2** illustrates a bottom, back, right side perspective view of the harvesting robot of FIG. **1**;

FIG. **3** illustrates a top, front, right side perspective view of a picking apparatus, according to the embodiment of FIG. **1**;

FIG. **4** illustrates a front view of a gripper of the picking apparatus of FIG. **3** in an open position;

FIG. **5** illustrates a front view of the gripper of FIG. **4** in a closed position;

FIG. **6** illustrates a top, front, left side perspective view of a carriage assembly, showing a stationary cam, and covers of a top base, a guide assembly, and a gear housing, according to the embodiment of FIG. **1**;

FIG. **7** illustrates a bottom, front, left side perspective view of various internal components of the carriage assembly of FIG. **6**, and not showing the stationary cam and the covers of the top base, the guide assembly, and the gear housing of FIG. **6**;

FIG. **8** illustrates a rear view of the carriage assembly of FIG. **6**, showing the stationary cam and the covers of the top base, the guide assembly, and the gear housing of FIG. **6**, and showing various internal components in the gear housing;

FIG. **9** illustrates a top, rear, left side perspective view of an actuation cam, an actuator, and a stationary cam of the carriage assembly of FIG. **6**;

FIG. **10** illustrates a rear view of the actuation cam, actuator, and stationary cam of FIG. **9**, and the picking apparatus of FIG. **3** with a gripper in the picking position being in the open position;

FIG. **11** illustrates a rear, right side perspective view of the actuation cam, actuator, and stationary cam of FIG. **9**, and the picking apparatus of FIG. **3** with the gripper of FIG. **10** in the picking position being in the closed position;

FIG. **12** illustrates a bottom, rear, right side perspective view of a carrier assembly, according to the embodiment of FIG. **1**;

FIG. **13** illustrates a top view of the harvesting robot of FIG. **1**, showing the carrier assembly of FIG. **12** coupled to the carriage assembly of FIG. **6** and the picking apparatus of FIG. **3**;

FIG. **14** illustrates a bottom, front, right side perspective view of a foliage displacement mechanism, according to another embodiment;

FIG. **15** illustrates a right side view of the harvesting robot of FIG. **1** and the foliage displacement mechanism of FIG. **14** hovering above a plant and a growing bed, with the foliage displacement mechanism in a retracted position;

FIG. **16** illustrates a top, rear view of the foliage displacement mechanism of FIG. **14** hovering above the plant of FIG. **15** in an extended position;

FIG. **17** illustrates a front view of a computer system that is suitable for implementing various embodiments for implementing a processing unit, according to an embodiment of the carrier assembly of FIG. **12**;

FIG. **18** illustrates a representative block diagram of an example of the elements included in the circuit boards inside a chassis of the computer system of FIG. **17**; and

FIG. **19** illustrates a flow chart for a method of providing a device for selectively harvesting crops on a plant, according to another embodiment.

For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the present disclosure. Additionally, elements in the drawing figures are not necessarily drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of embodiments of the present disclosure. The same reference numerals in different figures denote the same elements.

The terms "first," "second," "third," "fourth," and the like in the description and in the claims, if any, are used for distinguishing between similar elements and not necessarily for describing a particular sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments described herein are, for example, capable of operation in sequences other than those illustrated or otherwise described herein. Furthermore, the terms "include," and "have," and any variations thereof, are intended to cover a non-exclusive inclusion, such that a process, method, system, article, device, or apparatus that comprises a list of elements is not necessarily limited to those elements, but may include other elements not expressly listed or inherent to such process, method, system, article, device, or apparatus.

The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the apparatus, methods, and/or articles of manufacture

described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

The terms "couple," "coupled," "couples," "coupling," and the like should be broadly understood and refer to connecting two or more elements mechanically and/or otherwise. Two or more electrical elements may be electrically coupled together, but not be mechanically or otherwise coupled together. Coupling may be for any length of time, e.g., permanent or semi-permanent or only for an instant. "Electrical coupling" and the like should be broadly understood and include electrical coupling of all types. The absence of the word "removably," "removable," and the like near the word "coupled," and the like does not mean that the coupling, etc. in question is or is not removable.

As defined herein, two or more elements are "integral" if they are comprised of the same piece of material. As defined herein, two or more elements are "non-integral" if each is comprised of a different piece of material.

As defined herein, "approximately" can, in some embodiments, mean within plus or minus ten percent of the stated value. In other embodiments, "approximately" can mean within plus or minus five percent of the stated value. In further embodiments, "approximately" can mean within plus or minus three percent of the stated value. In yet other embodiments, "approximately" can mean within plus or minus one percent of the stated value.

DESCRIPTION OF EXAMPLES OF EMBODIMENTS

Various embodiments include a device for selectively harvesting crops on a plant. The device can include a picking apparatus. The picking apparatus can be rotatable around a central axis. The picking apparatus can include a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops. Each of the plurality of grippers can be adjustable between an open position and a closed position. Each of the plurality of grippers can be configured in the open position to open around the individual crop. Each of the plurality of grippers can be configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis.

A number of embodiments include a method of providing a device for selectively harvesting crops on a plant. The method can include providing a picking apparatus. The picking apparatus can be rotatable around a central axis. The picking apparatus can include a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops. The method also can include providing a carriage assembly. The carriage assembly can include a first rotational mechanism. The picking apparatus can be configured to be coupled to the first rotational mechanism. The first rotational mechanism can be configured to rotate the picking apparatus around the central axis in a rotational path with respect to the carriage assembly. Each of the plurality of grippers can be adjustable between an open position and a closed position. Each of the plurality of grippers can be configured in the open position to open around the individual crop. Each of the plurality of grippers can be configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis.

Some embodiments include a foliage displacement mechanism for facilitating harvesting crops on a plant. The foliage displacement mechanism can include a back surface configured to extend normal to a growing bed of the plant. The foliage displacement mechanism also can include a base configured to extend parallel to the growing bed from the back surface toward the plant. The foliage displacement mechanism further can include a curved surface extending from the base upward to the back surface. The foliage displacement mechanism also can include a channel bisecting a front portion of the base and extending upward through the curved surface, the channel being configured to surround a center of the plant when the foliage displacement mechanism is moved toward the plant. The foliage displacement mechanism can be configured, when moved toward the plant, to move the foliage upward and toward the center of the plant to expose at least a portion of the crops.

Turning to the drawings, FIG. **1** illustrates a top, front, left side perspective view of a harvesting robot **100**. FIG. **2** illustrates a bottom, back, right side perspective view of harvesting robot **100**. Harvesting robot **100** is merely exemplary, and embodiments of the harvesting robot are not limited to embodiments presented herein. The harvesting robot can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, harvesting robot **100** can include a picking apparatus **110**, a carriage assembly **140**, and/or a carrier assembly **170**. In several embodiments, harvesting robot **100** can be configured to harvest crops from plants. In some embodiments, harvesting robot **100** can be used to harvest crops such as strawberries from strawberry plants. In the same or other embodiments, harvesting robot **100** can be used to harvest crops such as tomatoes, peppers (e.g., bell peppers, chili peppers, etc.), oranges, and/or other suitable crops. In a number of embodiments, harvesting robot **100** can be configured to selectively pick crops (e.g., ripe crops) from plants, and leave other crops (e.g., unripe crops) on the plants.

Turning ahead in the drawings, FIG. **3** illustrates a top, front, right side perspective view of picking apparatus **110**. Picking apparatus **110** is merely exemplary, and embodiments of the picking apparatus are not limited to embodiments presented herein. The picking apparatus can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, picking apparatus **110** can be rotatable around a central axis **311**. In a number of embodiments, picking apparatus **110** can include one or more grippers, such as grippers **312**, **313**, **314**, and/or **315**. In various embodiments, each of the grippers (e.g., **312-315**) can be used to pick a different individual one of the crops. For example, gripper **312** can be used to pick a first strawberry; gripper **313** can be used to pick a second strawberry; gripper **314** can be used to pick a third strawberry; and/or gripper **315** can be used to pick a fourth strawberry. In a number of embodiments, picking apparatus **110** can include four grippers (e.g., **312-315**), such as shown in FIG. **3**. In other embodiments, the number of grippers (e.g., **312-315**) on picking apparatus **110** can be one, two, three, five, six, seven, eight, nine, ten, or another suitable number of grippers. In some embodiments, the number of grippers can be even numbered. In other embodiments, the number of grippers can be odd numbered. In several embodiments, the number of grippers (e.g., **312-315**) on picking apparatus **110** can be based on the average number of individual crops (e.g., strawberries, etc.) expected to be harvested from a plant, the time it takes to offload the individual crops from the grippers (e.g., **312-315**), a compromise (such as an optimal compromise) between the maximum number of individual crops expected to be har-

vested and the time it takes to offload the individual crops, and/or other suitable factors. Each gripper can be identical to the other grippers in picking apparatus **110**.

In a number of embodiments, the grippers (e.g., **312-315**) can be spaced apart and/or can extend radially from central axis **311**. In many embodiments, the grippers (e.g., **312-315**) can be facing radially outwards from a rotational circumference of picking apparatus **110**. In some embodiments, the gripper can be equally spaced apart on picking apparatus **110**. In several embodiments, picking apparatus **110** can include a frame **316**, which can include one or more spokes, such as spokes **317**, **318**, **319**, and/or **320**. In various embodiments, each gripper (e.g., **312-315**) can be attached to a different spoke (e.g., **317-320**). For example, as shown in FIG. **3**, gripper **312** can be attached to spoke **317**; gripper **313** can be attached to spoke **318**; gripper **314** can be attached to spoke **319**; and/or gripper **315** can be attached to spoke **320**. In other embodiments, frame **316** can be a solid wheel with or without spokes, and the grippers (e.g., **312-315**) can be attached to the solid wheel of frame **316**. In various embodiments, frame **316** can include an attachment mechanism, such as attachment mechanism **321**. In many embodiments, attachment mechanism **321** can be used to rotate picking apparatus **110** around central axis **311**.

Turning ahead in the drawings, FIG. **4** illustrates a front view of gripper **312** in an open position. FIG. **5** illustrates a front view of gripper **312** in a closed position. Gripper **312** is merely exemplary, and embodiments of the gripper are not limited to embodiments presented herein. The gripper can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, each of the other grippers (e.g., **313-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **3**) can be identical or similar to gripper **312**. In several embodiments, gripper **312** can be adjustable between the open position, as shown in FIG. **4**, and the closed position, as shown in FIG. **5**. In a number of embodiments, gripper **312** can be configured in the open position (as shown in FIG. **4**) to open around an individual crop, such as a single strawberry growing on a strawberry plant, or another suitable crop. In many embodiments, gripper **312** can be configured in the closed position (as shown in FIG. **5**) to securely hold the individual crop, such as strawberry **535**, when picking apparatus **110** (FIGS. **1-3**) is moved and/or rotated around central axis **311** (FIG. **3**).

In various embodiments, gripper **312** can include a first claw piece **410** and a second claw piece **420**. In other embodiments, gripper **312** can include a single claw or scoop piece and one or more support pieces. In yet other embodiments, gripper **312** can include three or more claw pieces. In many embodiments, first claw piece **410** can include a first claw frame **411** and/or second claw piece **420** can include a second claw frame **421**. In some embodiments, first claw frame **411** can provide rigid support for first claw piece **410**, and/or second claw frame **421** can provide rigid support for second claw piece **420**. In a number of embodiments, first claw frame **411** and/or second claw frame **421** can be made of a suitable rigid polymer (e.g., polycarbonate (PC), acrylonatrile butadiene styrene (ABS)), metal (e.g., aluminum), or another suitable material.

In many embodiments, first claw piece **410** can include a first claw surface **412**, and/or second claw piece **420** can include a second claw surface **422**. In a number of embodiments, first claw surface **412** can be attached to and/or can at least partially cover first claw frame **411**, and/or second claw surface **422** can be attached to and/or can at least partially cover second claw frame **421**. In a number of embodiments, first claw surface **412** and/or second claw surface **422** can be made of a soft and/or elastic material, such as silicone rubber, thermoplastic elastomer (TPE) (e.g., thermoplastic polyurethane (TPU)), rubber, foam, neoprene, or another suitable material that can provide a gentle, soft, and/or compliant surface for contacting, without damaging, the crops, and/or that can be suitable for contact with food. For example, first claw surface **412** and/or second claw surface **422** can be made of 20 A Shore durometer silicone rubber. First claw surface **412** and/or second claw surface **422** can be within a range of durometer, such as below 50 A Shore durometer.

In many embodiments, first claw piece **410** can include a first tip **413**, and/or second claw piece **420** can include a second tip **423**. In many embodiments, first tip **413** and/or second tip **423** can be wedge-shaped and/or configured to be inserted between crops to separate an individual crop from proximate crops (e.g., a cluster of crops) in order to pick the individual crop without damaging the proximate crops. For example, if a crop to be picked is located between two other nearby crops, first tip **413** can be configured to be wedged between the crop to be picked and another one of the nearby crops, and second tip **423** can be configured to be wedged between the crop to be picked and the other one of the nearby crops, which can separate and/or isolate the individual crop to be picked from the nearby crops without damaging the nearby crops.

In some embodiments, first claw piece **410** can include a retention surface **518**, and/or second claw piece **420** can include a retention surface **528**. Retention surface **518** and/or retention surface **528** can be configured to securely hold the crop (e.g., strawberry **535**) in gripper **312**. In several embodiments, such as shown in FIGS. **5**, retention surface **518** and/or retention surface **528** can each include a concave surface, which can at least partially surround the crop (e.g., strawberry **535**) to facilitate securely holding the crop.

In several embodiments, gripper **312** can be spring biased to be in the open position, as shown in FIG. **4**. In a number of embodiments, gripper **312** can include a displacement block **430**, which can be coupled to spoke **317**, and which can be configured to slide radially inward and outward along spoke **317**. In several embodiments, displacement block **430** can include a pin **431**, which can facilitate coupling displacement block **430** to spoke **317**. In many embodiments, spoke **317** can include a compression spring **432**, which can compress when displacement block **430** is adjusted outward along spoke **317** to adjust gripper **312** to the closed position, as shown in FIG. **5**, and which can be biased to press displacement block **430** inward along spoke **317** to adjust gripper **312** to the open position, as shown in FIG. **4**. In various embodiments, gripper **312** can include one or more spring guards, such as spring guard **433** and/or spring guard **434**, which can cover and/or protect compression spring **432**.

In many embodiments, a first claw piece **410** can include a first displacement mounting portion **416** and a spoke mounting portion **417**, and/or second claw piece **420** can include a second displacement mounting portion **426** and a spoke mounting portion **427**. In a number of embodiments, spoke mounting portion **417** and/or spoke mounting portion **427** can be hingedly coupled to spoke **317**, such as at a hinge **419** and/or a hinge **429**, respectively. In several embodiments, first displacement mounting portion **416** and/or second displacement mounting portion **426** can be linkedly attached to displacement block **430**, such that adjusting the position of displacement block **430** can adjust first claw piece **410** and/or second claw piece **420** between the open position, as shown in FIG. **4**, and the closed position, as

shown in FIG. **5**, such as by rotating first claw piece **410** around hinge **419** and/or rotating second claw piece **420** around hinge **429**.

In many embodiments, gripper **312** can include a first strip **414**, a first linkage piece **415**, a second strip **424**, and/or a second linkage piece **425**. First strip **414** and/or second strip **424** can be coupled to displacement block **430**. First linkage piece **415** can be hingedly coupled to first displacement mounting portion **416** at a hinge **418**, and can be coupled, such as slidably coupled, to first strip **414**. Second linkage piece **425** can be hingedly coupled to second displacement mounting portion **426** at a hinge **428**, and can be coupled, such as slidably coupled, to second strip **424**. In many embodiments, first strip **414** and/or second strip **424** can be made of a flexible and/or abrasive-resistant semi-rigid material, such as ultra-high-molecular-weight (UHMW) polyethylene (UHMWPE). As shown in FIGS. **4-5**, as displacement block **430** is adjusted radially outward on spoke **317**, first strip **414** can push first claw piece **410** forward to rotate around hinge **419** to the closed position, and first linkage piece **415** can slide outwardly along first strip **414** away from displacement block **430** as the position of first displacement mounting portion **416** is adjusted. Similarly, as displacement block **430** is adjusted radially outward on spoke **317**, second strip **424** can push second claw piece **420** forward to rotate around hinge **429** to the closed position, and second linkage piece **425** can slide outwardly along second strip **424** away from displacement block **430** as the position of second displacement mounting portion **426** is adjusted.

In several embodiments, as displacement block **430** is adjusted radially outward on spoke **317**, first strip **414** and/or second strip **424** can bend backward (i.e., toward a center of frame **316** (FIG. **3**)) to account for first claw piece **410** and/or second claw piece **420**, respectively, not fully pushing forward in their rotation around hinge **419** and/or hinge **429**, respectively. For example, if gripper **312** is utilized to pick a large-size crop, the size of the crop can prevent first claw piece **410** and/or second claw piece **420** from being fully pushed forward in their rotation around hinge **419** and/or hinge **429**, respectively. When displacement block **430** is adjusted radially outward on spoke **317**, first strip **414** and/or second strip **424** can provide spring-loaded bias on first claw piece **410** and/or second claw piece **420**, respectively, to securely hold a crop (e.g., strawberry **535**) in gripper **312**. In a number of embodiments, the spring-loaded bending of first strip **414** and/or second strip **424** can advantageously allow gripper **312** to pick crops of various different sizes and securely hold those different-sized crops without damaging the crops. For example, gripper **312** can be configured to pick strawberries ranging from small-sized strawberries to large-sized strawberries.

Turning ahead in the drawings, FIG. **6** illustrates a top, front, left side perspective view of carriage assembly **140**, showing a stationary cam **669**, and covers of a top base **641**, a guide assembly **651**, and a gear housing **652**. FIG. **7** illustrates a bottom, front, left side perspective view of various internal components of carriage assembly **140**, and not showing stationary cam **669** and the covers of top base **641**, guide assembly **651**, and gear housing **652**. FIG. **8** illustrates a rear view of carriage assembly **140**, showing stationary cam **669** and the covers of top base **641**, guide assembly **651**, and gear housing **652**, and showing various internal components in gear housing **652**. Carriage assembly **140** is merely exemplary, and embodiments of the carriage assembly are not limited to embodiments presented herein. The carriage assembly can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, carriage assembly can include a carriage support assembly **640** and a carriage **650**. In many embodiments, carriage **650** can be vertically adjustable with respect to carriage support assembly **640**.

In a number of embodiments, carriage support assembly **640** can include top base **641** and/or a bottom base **642**. In several embodiments, carriage support assembly **640** can include a left guide pole **643** and/or a right guide pole **644**, which can each extend from top base **641** to bottom base **642**. In some embodiments carriage support assembly can include a vertical adjustment shaft **645**. In many embodiments, vertical adjustment shaft **645** can extend from top base **641** to bottom base **642**, and can rotate with respect to top base **641** and bottom base **642**. In a number of embodiments, vertical adjustment shaft **645** can be a threaded shaft, such as a lead screw. In a number of embodiments, top base **641** can include a gear enclosure **647**. In various embodiments, carriage support assembly **640** can include a motor **646**. Motor **646** can be a stepper motor or another suitable motor. In a number of embodiments, motor **646** can control the rotation of vertical adjustment shaft **645**. For example, as shown in FIG. **7**, which shows the components within gear enclosure **647** (FIGS. **6**, **8**) and which does not show the cover of gear enclosure **647** itself, motor **646** can be coupled to a gear **746** inside first gear enclosure **647**, and vertical adjustment shaft **645** can be coupled to a gear **745** inside gear enclosure **647** (FIGS. **6**, **8**). Gear **745** can be positioned to engage with gear **746** within gear enclosure **647** (FIGS. **6**, **8**). By rotating vertical adjustment shaft **645**, motor **646** can control the vertical position of carriage **650**.

In several embodiments, carriage **650** can include guide assembly **651**. As shown in FIG. **7**, which shows the components within guide assembly **651** and which does not show the cover of guide assembly **651** itself, guide assembly **651** can include left linear bearings **750** and/or right linear bearings **751**. In various embodiments, left linear bearings **750** can be guide the vertical motion of carriage **650** along left guide pole **643**, and/or right linear bearings **751** can guide the vertical motion of carriage **650** along right guide pole **644**. In several embodiments, carriage assembly **140** can include one or more springs, such as spring **648** and spring **849**, which can extend from carriage **650** to top base **641** of carriage support assembly **640**. Spring **648** and spring **849** can be extension springs, which can beneficially support carriage **650** to decrease the force required to vertically lift carriage **650** with respect to carriage support assembly **640**.

In many embodiments, carriage **650** can include gear housing **652**. As shown in FIG. **7**, which shows the components inside gear housing **652** and which does not show the cover of gear housing **652** itself, carriage **650** can include a carriage position piece **752**, which can be attached to vertical adjustment shaft **645** and can be configured to vertically adjust the position of the carriage upon rotational movement of vertical adjustment shaft **645**. In several embodiments, carriage position piece **752** can be a lead screw nut that has a threading corresponding to vertical adjustment shaft **645**.

In a number of embodiments, carriage **650** can include a rotational shaft **655**. Rotational shaft **655** can be configured to couple to picking apparatus **110** (FIG. **1-3**). For example, rotational shaft **655** can attach to attachment mechanism **321** (FIG. **3**). In many embodiments, carriage **650** can include a motor **654**. Motor **654** can be a stepper motor or another suitable motor. In several embodiments, motor **654** can control the rotation of a rotational shaft **655** and/or picking apparatus **110**. For example, motor **654** can be configured to

control the rotational positioning of the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**). As shown in FIG. **8**, which shows various internal components within gear housing **652** (FIG. **6**), motor **654** can be coupled to a gear **854** inside gear housing **652** (FIG. **6**), and rotational shaft **655** can be coupled to a gear **855** inside gear housing **652** (FIG. **6**). Gear **854** can be positioned to engage with gear **855** within gear housing **652** (FIG. **6**). For example, gear **854** can be a worm, and gear **855** can be a corresponding worm gear. By rotating rotational shaft **655**, motor **654** can control the rotational position of picking apparatus **110** (FIG. **1-3**).

In several embodiments, carriage **650** can include stationary cam **669** (FIGS. **6**, **8**, not shown in FIG. **7**). In a number of embodiments, rotational shaft **655** can pass through a central region of stationary cam **669**. In many embodiments, stationary cam **669** can facilitate controlling the adjustment position (e.g., open position, closed position) of the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) as the grippers (e.g., **312-315** (FIG. **3**)) rotate around central axis **311** (FIG. **3**), as shown in FIGS. **10-11** and described below in greater detail.

In some embodiments, carriage **650** can include a actuation cam **660**. Actuation cam **660** can be configured to facilitate controlling the adjustment position (e.g., open position, closed position) of the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) as each of the grippers (e.g., **312-315** (FIG. **3**)) are positioned above and utilized to pick a crop, as shown in FIG. **10-11** and described below in greater detail. In many embodiments, actuation cam **660** can be a snail drop cam. In various embodiments, carriage **650** can include a motor **653**. Motor **653** can be a stepper motor or another suitable motor. In many embodiments, motor **653** can be coupled to and/or can control the rotation of actuation cam **660**

In some embodiments, carriage **650** can include an actuator **661**. As shown in FIG. **7**, which shows components of carriage **650** (FIGS. **6**, **8**) with stationary cam **669** (FIGS. **6**, **8**) removed, actuator can include a drive portion **761**, which can fit vertically between left actuator bearings **766** and right actuator bearings **767** on carriage **650** (FIGS. **6**, **8**), and can adjust vertically to transfer the control position of actuation cam **660** to the gripper (e.g., **312-315** (FIG. **3**)), which can adjust the adjustment position (e.g., open position, closed position) of the gripper (e.g., **312-315** (FIG. **3**)), as shown in FIGS. **10-11** and described below in greater detail. In various embodiments, drive portion **761** can include a sliding slot **764**, which can allow actuator **661** to surround rotational shaft **655**, and which can allow vertical movement of actuator **661** with respect to rotational shaft **655**. In a number of embodiments, actuator **661** can include guide portions **762**, which can each fit horizontally between left actuator bearings **766** and right actuator bearings **767**, respectively. For example, guide portions **762** can guide the vertical adjustment of actuator **661** between, and prevent the vertical movement beyond, the top bearings and bottom bearings of left bearings **766** and/or right bearings **767**. In certain embodiments guide portions **762** can include attachment pieces **763**, which can attach actuator **661** to attachment bases **765** on gear housing **652** (FIGS. **6**, **8**) of carriage **650** (FIGS. **6**, **8**) via springs (e.g., extension springs) or other suitable elastic components, in order to bias actuator **661** in a vertically upward position to engage with actuation cam **660**.

Turning ahead in the drawings, FIG. **9** illustrates a top, rear, left side perspective view of actuation cam **660**, actuator **661**, and stationary cam **669**. Actuation cam **660**, actuator **661**, and stationary cam **669** are merely exemplary, and embodiments of the actuation cam, actuator, and stationary cam are not limited to embodiments presented herein. The actuation cam, actuator, and stationary cam can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, actuator **661** can include a cam interface piece **960**, which can follow the shape of actuation cam **660** to adjust the position of actuator **661**. In several embodiments, actuation cam **660** can be attached to motor **653** (FIGS. **6-8**) at rotation point **961**, and actuation cam **660** can rotate around rotation point **961**. In many embodiments, actuation cam **660** can rotate in a counter-clockwise direction, as viewed from the rear perspective shown FIG. **9**. As actuation cam **660** rotates, cam interface piece **960** can move along actuation cam **660** from a base point **962** of actuation cam **660** to a peak point **963** of actuation cam **660**, which can push actuator **661** vertically downward. As actuation cam **660** rotates further, cam interface piece **960** can drop back from peak point **963** to base point **962**.

In several embodiments, actuator **661** can include a gripper interface portion **969**, which can interface with a gripper (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) to adjust the adjustment position of the gripper (e.g., **312-315** (FIG. **3**)) between the open position (as shown in FIG. **4**) and the closed position (as shown in FIG. **5**). The gradual, continuous increase of actuation cam **660** can beneficially allow motor **653** (FIGS. **6-8**) to precisely control the vertical position of actuator **661**, which can advantageously allow motor **653** to precisely control the adjustment position of the gripper (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**). For example, motor **653**, actuation cam **660**, and actuator **661** can be used to precisely adjust the position of first tip **413** (FIGS. **4-5**) of first claw piece **410** (FIGS. **4-5**) and second tip **423** (FIGS. **4-5**) of second claw piece **420** (FIGS. **4-5**) in order to fit around an individual crop to be picked, and to separate and/or isolate the individual crop to be picked from the other nearby crops without damaging the nearby crops.

In a number of embodiments, stationary cam **669** can include a circular slot **968**, which can be configured to surround rotational shaft **655** (FIGS. **6-7**). In several embodiments, stationary cam **669** can have a fixed position with respect to carriage **650** (FIGS. **6**, **8**), and the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) can rotate around stationary cam **669**. In many embodiments, the rotational path of stationary cam **669** can include a first portion **964**. Stationary cam **669** can be configured to hold the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) in a closed position (as shown in FIG. **5**) along first portion **964** of the rotational path. In several embodiments, the rotational path of stationary cam **669** can include a second portion **965**. In a number of embodiments, second portion **965** of the rotational path can include a release position **967** and a picking position **966**. Stationary cam **669** can be configured to allow the grippers (e.g., **312-315** (FIG. **3**)) on picking apparatus **110** (FIGS. **1-3**) to open to the open position (as shown in FIG. **4**) along second portion **965** of the rotational path from release position **967** to picking position **966**.

Turning ahead in the drawings, FIG. **10** illustrates a rear view of actuation cam **660**, actuator **661**, stationary cam **669**, and picking apparatus **110** with gripper **312** in picking position **966** being in the open position. FIG. **11** illustrates a rear, right side perspective view of actuation cam **660**, actuator **661**, stationary cam **669**, and picking apparatus **110** with gripper **312** in picking position **966** being in the closed

position. In a number of embodiments, gripper **312** can include a displacement pin **1032** and/or a bearing **1012**. In a number of embodiments, displacement pin **1032** can be identical to or attached to pin **431** (FIGS. **4-5**). In many embodiments, displacement pin **1032** can be coupled to displacement block **430** (FIGS. **4-5**), such that adjusting displacement pin **1032** can adjust displacement block **430**. In many embodiments, bearing **1012** can be centered on displacement pin **1032**, and can rotate along the rotational path of stationary cam **669**. Similarly, gripper **313** can include a displacement pin **1033** and/or a bearing **1013**; gripper **314** can include a displacement pin **1034** and/or a bearing **1014**; and/or gripper **315** can include a displacement pin **1035** and/or a bearing **1015**. Displacement pin **1033**, displacement pin **1034**, and/or displacement pin **1035** can be similar or identical to displacement pin **1032**. Bearing **1013**, bearing **1014**, and/or bearing **1015** can be similar or identical to bearing **1012**.

In many embodiments, motor **654** (FIGS. **6-8**) can rotate picking apparatus **110** in a counter-clockwise direction, as viewed from the rear perspective shown in FIGS. **10-11**. Gripper **312** can be rotated to picking position **966** of second portion **965** of the rotational path of the grippers (e.g., **312-315** (FIG. **3**)) along stationary cam **669**. In many embodiments, stationary cam **669** can include a stopping edge **1066**, which can stop bearing **1012** in the rotation of picking apparatus **110** to stop gripper **312** at picking position **966**. In many embodiments, when gripper **312** is in picking position **966**, gripper **312** can be facing downward to allow gripper **312** to pick a crop from a growing bed. When gripper **312** is rotated to picking position **966**, actuation cam **660** can be rotated such that cam interface piece **960** of actuator **661** can be at base point **962** of actuation cam **660** and actuator **661** is adjusted upwards (e.g., retracted) with respect to stationary cam **669**. When actuator **661** is in the retracted position, as shown in FIG. **10**, gripper interface portion **969** of actuator **661** can be at or proximate to second portion **965** of stationary cam **669**, such that gripper **312** can remain in the open position.

In several embodiments, as gripper **312** rotates toward picking position **966**, gripper **315** can rotate along the rotational path of stationary cam **669** from first portion **964** to second portion **965** at release position **967**. In many embodiments, stationary cam **669** can include a release edge **1067**, which can allow gripper **315** to gradually open from the closed position (as shown in FIG. **5**) to the open position (as shown in FIG. **4**) at release position **967**. When gripper **315** is rotated to release position **967** and opens to the open position, gripper **315** can release a crop that it is holding, such as in a collection device. When gripper **312** is at picking position **966** and gripper **315** is at release position **967**, grippers **313** and **314** can be positioned along first portion **964** of the rotational path of stationary cam **669**, which can hold grippers **313** and **314** in the closed position, as shown in FIG. **10**. For example, grippers **313** and **314** can each be holding a crop.

In many embodiments, at picking position **966** and in the open position, as shown in FIG. **10**, gripper **312** can be ready to pick a crop from a plant. In several embodiments, carrier **170** (FIG. **1**) can move carriage support assembly **140** such that gripper **312** is positioned over the crop to be picked. Motor **653** (FIGS. **6-8**) can rotate actuation cam **660** to engage gripper interface portion **969** of actuator **661** with displacement pin **1032** of gripper **312** to adjust the position of first claw piece **410** (FIGS. **4-5**) and second claw piece **420** (FIGS. **4-5**) of gripper **312** in order to fit around the individual crop to be picked. For example, if the crop is a larger, such as a large-sized strawberry, gripper **312** can be set to a wider opening in the open position, and if the crop is smaller, such as a small-sized strawberry, gripper **312** can be set to a narrow opening in the open position, which can allow gripper **312** to separate and/or isolate the individual crop to be picked from the other nearby crops without damaging the nearby crops.

When gripper **312** is adjusted to the appropriate opening width for the crop to be picked, carriage support assembly **140** can lower carriage **150** such that first claw piece **410** (FIGS. **4-5**) and second claw piece **420** (FIGS. **4-5**) of gripper **312** can surround the crop to be picked. Motor **653** (FIGS. **6-8**) can rotate actuation cam **660** such that cam interface piece **960** can move along actuation cam **660** to peak point **963**, which can push extend actuator **661** to an extended position, as shown in FIG. **11**. As actuator **661** is extended, gripper interface portion **969** of actuator **661** can push displacement pin **1032** to adjust the position of gripper **312** to the closed position (as shown in FIG. **11**). When gripper **312** is in the closed position, bearing **1012** of gripper **312** can be extended beyond stopping edge **1066** of stationary cam **669**, such that gripper **312** can be rotated along first portion **964** of the rotational path of stationary cam **669**. In many embodiments, gripper **312** can securely hold the picked crop as gripper **312** rotates along first portion **964**. After gripper **312** picks the crop, motor **654** (FIGS. **6-8**) can rotate picking apparatus **110** such that gripper **315** is rotated to picking position **966**. Although picking apparatus **110** is shown with **4** grippers (e.g., **312-315**), picking apparatus **110** can include fewer or additional grippers, and first portion **964** and second portion **965** of the rotational path of stationary cam **669** can be adjusted accordingly.

Turning ahead in the drawings, FIG. **12** illustrates a bottom, rear, right side perspective view of carrier assembly **170**. FIG. **13** illustrates a top view of harvesting robot **100**, showing carrier assembly **170** coupled to carriage assembly **140** (FIGS. **1-2**, **6-8**) and picking apparatus **110**. Carrier assembly **170** is merely exemplary, and embodiments of the carrier assembly are not limited to embodiments presented herein. The carrier assembly can be employed in many different embodiments or examples not specifically depicted or described herein. In several embodiments, carrier assembly **170** can include a mounting bearing **1274**. In many embodiments, carrier assembly **170** and/or harvesting robot **100** can be mounted above a plant to be harvested at mounting bearing **1274**. In a number of embodiments, mounting bearing **1274** can be a geared slewing bearing, which can be used to rotate carrier assembly **170** and/or harvesting robot **100** with respect to the plant. For example, harvesting robot **100** can rotate in a clockwise and/or counterclockwise direction, as viewed from the top perspective shown FIG. **13**, around mounting bearing **1274**.

In many embodiments, carrier assembly **170** can include an carriage attachment base **1284**, which can be configured to couple to top base **641** (FIGS. **6**, **8**) in order to couple carriage assembly **140** to carrier assembly **170** and to move carriage assembly **140** with respect carrier assembly **170**. In a number of embodiments, carrier assembly **170** can include a motor **1275**. Motor **1275** can be a stepper motor or another suitable motor. In several embodiments, motor **1275** can control the rotation of an adjustment shaft **1278** to adjust the position of carriage attachment base **1284** and/or carriage assembly **140** with respect to mounting bearing **1274**. In a number of embodiments, adjustment shaft **1278** can be a threaded shaft, such as a lead screw.

In some embodiments, carrier assembly **170** can include a foliage displacement base **1281**, which can be coupled to

a foliage displacement mechanism **1400**, as shown in FIG. **14** and described below. In a number of embodiments, foliage displacement mechanism **1400** (FIG. **14**) can be attached to foliage displacement base **1281** at attachment portions **1282** and **1383**. In many embodiments, carrier assembly **170** can include a motor **1276**. Motor **1276** can be a stepper motor or another suitable motor. In various embodiments, motor **1276** can control the rotation of an adjustment shaft **1277** to adjust the position of foliage displacement base **1281** with respect to mounting bearing **1274**. In a number of embodiments, adjustment shaft **1277** can be a threaded shaft, such as a lead screw.

In several embodiments, carrier assembly **170** can include rails **1279** and **1280**, which can allow carriage attachment base **1284** and/or foliage displacement base **1281** to adjustably slide radially inward and outward with respect to mounting bearing **1274**. In many embodiments, carrier assembly **170** can include one or more imaging sensors **1290** and/or **1291**. Imaging sensors **1290** and/or **1291** can be cameras configured to detect optical image information. In a number of embodiments, carrier assembly **1271** can include an electronics unit **1271**. In some embodiments, electronics unit **1271** can include a control unit **1272** and/or a processing unit **1273**. In a number of embodiments, processing unit **1273** can include one or more processors configured to receive information from imaging sensors **1290** and/or **1291** to determine the location of the crops to be harvested. For example, processing unit can be configured to determine that certain crops are ripe and ready to be harvested, and other crops are not yet ripe or are damaged, and should not be harvested. In various embodiments, control unit **1272** can be electrically coupled to processing unit **1273** and/or can include one or more controllers to control the motors in harvesting robot **100**, such as motor **646** (FIGS. **6-8**), motor **653** (FIGS. **6-8**), motor **654** (FIG. **6-8**), motor **1275** (FIGS. **12-13**), and/or motor **1276** (FIGS. **12-13**).

Turning ahead in the drawings, FIG. **14** illustrates a bottom, front, right side perspective view of a foliage displacement mechanism **1400**. Foliage displacement mechanism **1400** is merely exemplary, and embodiments of the foliage displacement mechanism are not limited to embodiments presented herein. The foliage displacement mechanism can be employed in many different embodiments or examples not specifically depicted or described herein. In many embodiments, foliage displacement mechanism **1400** can be configured to move foliage of a plant to expose at least a portion of the crops under the foliage, which can allow image sensors **1290** (FIGS. **12-13**) and/or **1291** (FIGS. **12-13**) to detect the crops and/or allow the grippers (e.g., **312-315** (FIGS. **3**, **10-11**)) of picking apparatus **110** (FIGS. **1-3**) to pick the crops.

In several embodiments, foliage displacement mechanism **1400** can include a back surface **1410**. In many embodiments, back surface **1410** can have a planar rectangular shape. In a number of embodiments, back surface **1410** can be configured to extend normal to a growing bed of the plant, as shown in FIG. **15** and described below. In several embodiments, foliage displacement mechanism **1400** can include a base **1420**. Base **1420** can be configured to extend parallel to the growing bed of the plant from a back edge **1411** at back surface **1410** toward the center of the plant, as shown in FIG. **15** and described below. In a number of embodiments, base **1420** can have a semicircular shape.

In several embodiments, foliage displacement mechanism **1400** can include a surface **1440**. Surface **1440** can extend from base **1420** upward to back surface **1410**. In a number of embodiments, at least one or more portions of surface **1440** can be curved and/or have a concave shape. In some embodiments, at least one or more portions of surface **1440** can be shaped as at least a portion of an ellipses. In several embodiments, foliage displacement mechanism **1400** can include a channel **1450**. In many embodiments, channel **1450** can extend from base **1420** at a bottom channel portion **1451** upwards through surface **1440** to a top channel portion **1452**. In some embodiments, base **1420** can extend outward toward the plant from a left side of back surface **1410** to a left front portion **1421** and from a right side of back surface **1410** to a right front portion **1422**. In many embodiments, base **1420** can recede back toward back surface **1410** in the center of base **1420** between left front portion **1421** and right front portion **1422** to bottom channel portion **1451**.

In a number of embodiments, foliage displacement mechanism **1400** can include attachment mechanisms **1430** and/or **1431**. Attachment mechanisms **1430** and **1431** can be configured to attach foliage displacement mechanism **1400** to foliage displacement base **1281** (FIGS. **12-13**) at attachment portions **1383** (FIG. **13**) and/or **1282** (FIGS. **12-13**), respectively. Motor **1276** can be configured to adjust the position of foliage displacement mechanism **1400** to move foliage displacement mechanism **1400** toward or away from the plant. In many embodiments, as foliage displacement mechanism **1400** is moved toward the plant, foliage displacement mechanism **1400** can be positioned such that the channel **1450** surrounds the center of the plant. In a number of embodiments, foliage displacement mechanism **1400** can be configured, when moved toward the plant, to move the foliage upward and toward the center of the plant. For example, the curves on surface **1440** can be configured to lift the foliage upwards and towards the center of the plant, which can advantageously prevent damaging and/or tangling the foliage (such as the leaves, vines, and/or blossoms) of the plant.

Turning ahead in the drawings, FIG. **15** illustrates a right side view of harvesting robot **100** and foliage displacement mechanism **1400** hovering above a plant **1510** and growing bed **1501**, with foliage displacement mechanism **1400** in a retracted position. To assist with water run-off, growing bed **1501** can be slightly angled. In other examples, growing bed can be flat. Plant **1510** can be a strawberry plant, as shown in FIG. **15**. In other examples, plant **1510** can be a tomato plant, a pepper (e.g., bell peppers, chili peppers, etc.) plant, an orange tree, or another suitable plant. As shown in FIG. **15**, plant **1510** can have a center **1513** (e.g., a crown of a strawberry plant), and foliage **1512**, such as leaves, vines, and/or blossoms, that grow above growing bed **1501**. Plant **1510** can have crops **1511** that, when ripe, are located on growing bed **1501**. At least some of crops **1511** can be covered by foliage **1512**.

In many embodiments, such as shown in FIG. **15**, harvesting robot **100** can be mounted and/or supported such that central axis **311** of picking apparatus **110** is parallel to growing bed **1501**. In several embodiments, foliage displacement mechanism **1400** can be attached to carrier mechanism **170** at attachment portion **1282** and/or attachment portion **1383** (FIG. **13**) on **1281** with one or more attachment poles, such as attachment pole **1520**. Carrier mechanism **170** can adjust foliage displacement mechanism **1400** from a retracted position, as shown in FIG. **15**, toward plant **1510** to move foliage **1512** upward and toward center **1513** of plant **1510** to expose crops **1511** to be detected by image sensor **1290** and/or image sensor **1291** (FIGS. **12-13**) and/or picked by harvesting robot **100**. In many embodi-

ments, center **1513** can fit within channel **1450** (FIG. **14**) when foliage displacement mechanism **1400** is moved toward plant **1510**.

In several embodiments, mounting bearing **1274** can be centered above plant **1510**. When mounting bearing **1274** is centered above plant **1510**, mounting bearing **1274** can be configured to rotate harvesting robot **100**, carrier assembly **170**, carriage assembly **140**, picking apparatus **110**, and/or foliage displacement mechanism **1400** around plant **1510**. When a crop, such as one of crops **1511**, is located to be picked, (a) mounting bearing **1274** can rotate carrier assembly **170** such that the gripper (e.g., **312-315** (FIG. **3**)) in picking position **966** (FIGS. **9-11**) is radially in a line extending from center **1513** of plant **1510** through the crop (e.g., **1511**) to be picked, (b) carrier assembly **170** can move carriage assembly **140** radially inward toward plant **1510**, and (c) carriage assembly **140** can lower carriage **650** (FIGS. **6**, **8**) to lower picking apparatus **110** to allow a gripper (e.g., **312-315** (FIG. **3**)) to close and pick the crop (e.g., **1511**). In some embodiments, the motion of harvesting robot **100** can beneficially conserve motion, and/or can do a minimum amount of movement, such as to harvest an average maximum number of crops (e.g., **1511**) from plant **1510** in one rotation. For example, in some embodiments, harvesting robot **100** can be configured to harvest three crops from plant **1510**. In other embodiments, harvesting robot **100** can be configured to harvest fewer or additional crops from plant **1510**. In a number of embodiments, the picked crops can be deposited in a collection device as harvesting robot **100** moves to another plant.

Turning ahead in the drawings, FIG. **16** illustrates a top, rear view of foliage displacement mechanism **1400** hovering above plant **1510** in an extended position. In many embodiments, when foliage displacement mechanism **1400** is extended toward plant **1510**, moving foliage **1512** (FIG. **15**), image sensors **1290** and/or **1291** (FIGS. **12-13**) can detect crops **1511** on growing bed **1501**, and processing unit **1273** (FIGS. **12-13**) can determine the crops to be harvested, such as based on ripeness. In many embodiments, harvesting robot **100** (FIGS. **1-2**, **13**, **15**) can rotate around plant **1510** with foliage displacement mechanism **1400** in the extended position, as shown in FIG. **16**, in order for processing unit **1273** (FIGS. **12-13**) to determine which of the crops (e.g., **1511**) are the best crops to be picked.

Turning ahead in the drawings, FIG. **17** illustrates an exemplary embodiment of computer system **1700**, all of which or a portion of which can be suitable for implementing processing unit **1273** (FIGS. **12-13**). As an example, a different or separate one of chassis **1702** (and all or a portion of its internal components) can be suitable for implementing processing unit **1273** (FIGS. **12-13**). Furthermore, one or more elements of computer system **1700** (e.g., refreshing monitor **1706**, keyboard **1704**, and/or mouse **1710**, etc.) can also be appropriate for implementing the techniques described herein. Computer system **1700** comprises chassis **1702** containing one or more circuit boards (not shown), Universal Serial Bus (USB) port **1712**, Compact Disc Read-Only Memory (CD-ROM) and/or Digital Video Disc (DVD) drive **1716**, and hard drive **1714**. A representative block diagram of the elements included on the circuit boards inside chassis **1702** is shown in FIG. **18**. Central processing unit (CPU) **1810** in FIG. **18** is coupled to system bus **1814** in FIG. **18**. In various embodiments, the architecture of CPU **1810** can be compliant with any of a variety of commercially distributed architecture families.

Continuing with FIG. **18**, system bus **1814** also is coupled to memory storage unit **1808**, where memory storage unit **1808** comprises both read only memory (ROM) and random access memory (RAM). Non-volatile portions of memory storage unit **1808** or the ROM can be encoded with a boot code sequence suitable for restoring computer system **1700** (FIG. **17**) to a functional state after a system reset. In addition, memory storage unit **1808** can comprise microcode such as a Basic Input-Output System (BIOS). In some examples, the one or more memory storage units of the various embodiments disclosed herein can comprise memory storage unit **1808**, a USB-equipped electronic device, such as, an external memory storage unit (not shown) coupled to universal serial bus (USB) port **1712** (FIGS. **17-18**), hard drive **1714** (FIGS. **17-18**), and/or CD-ROM or DVD drive **1716** (FIGS. **17-18**). In the same or different examples, the one or more memory storage units of the various embodiments disclosed herein can comprise an operating system, which can be a software program that manages the hardware and software resources of a computer and/or a computer network. The operating system can perform basic tasks such as, for example, controlling and allocating memory, prioritizing the processing of instructions, controlling input and output devices, facilitating networking, and managing files. Some examples of common operating systems can comprise Microsoft® Windows® operating system (OS), Mac® OS, UNIX® OS, and Linux® OS.

As used herein, "processor" and/or "processing module" means any type of computational circuit, such as but not limited to a microprocessor, a microcontroller, a controller, a complex instruction set computing (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a graphics processor, a digital signal processor, or any other type of processor or processing circuit capable of performing the desired functions. In some examples, the one or more processors of the various embodiments disclosed herein can comprise CPU **1810**.

In the depicted embodiment of FIG. **18**, various I/O devices such as disk controller **1804**, graphics adapter **1824**, video controller **1802**, keyboard adapter **1826**, mouse adapter **1806**, network adapter **1820**, and other I/O devices **1822** can be coupled to system bus **1814**. Keyboard adapter **1826** and mouse adapter **1806** are coupled to keyboard **1704** (FIGS. **17-18**) and mouse **1710** (FIGS. **17-18**), respectively, of computer system **1700** (FIG. **17**). While graphics adapter **1824** and video controller **1802** are indicated as distinct units in FIG. **18**, video controller **1802** can be integrated into graphics adapter **1824**, or vice versa in other embodiments. Video controller **1802** is suitable for refreshing monitor **1706** (FIGS. **17-18**) to display images on a screen **1708** (FIG. **17**) of computer system **1700** (FIG. **17**). Disk controller **1804** can control hard drive **1714** (FIGS. **17-18**), USB port **1712** (FIGS. **17-18**), and CD-ROM drive **1716** (FIGS. **17-18**). In other embodiments, distinct units can be used to control each of these devices separately.

In some embodiments, network adapter **1820** can comprise and/or be implemented as a WNIC (wireless network interface controller) card (not shown) plugged or coupled to an expansion port (not shown) in computer system **1700** (FIG. **17**). In other embodiments, the WNIC card can be a wireless network card built into computer system **1700** (FIG. **17**). A wireless network adapter can be built into computer system **1700** by having wireless communication capabilities integrated into the motherboard chipset (not shown), or implemented via one or more dedicated wireless communication chips (not shown), connected through a PCI (peripheral component interconnector) or a PCI express bus

of computer system **1700** (FIG. **17**) or USB port **1712** (FIG. **17**). In other embodiments, network adapter **1820** can comprise and/or be implemented as a wired network interface controller card (not shown).

Although many other components of computer system **1700** (FIG. **17**) are not shown, such components and their interconnection are well known to those of ordinary skill in the art. Accordingly, further details concerning the construction and composition of computer system **1700** and the circuit boards inside chassis **1702** (FIG. **17**) are not discussed herein.

When computer system **1700** in FIG. **17** is running, program instructions stored on a USB-equipped electronic device connected to USB port **1712**, on a CD-ROM or DVD in CD-ROM and/or DVD drive **1716**, on hard drive **1714**, or in memory storage unit **1808** (FIG. **18**) are executed by CPU **1810** (FIG. **18**). A portion of the program instructions, stored on these devices, can be suitable for carrying out at least part of the techniques described above.

Although computer system **1700** is illustrated as a desktop computer in FIG. **17**, there can be examples where computer system **1700** may take a different form factor while still having functional elements similar to those described for computer system **1700**. In some embodiments, computer system **1700** may comprise a single computer, a single server, or a cluster or collection of computers or servers, or a cloud of computers or servers. Typically, a cluster or collection of servers can be used when the demand on computer system **1700** exceeds the reasonable capability of a single server or computer. In certain embodiments, computer system **1700** may comprise a portable computer, such as a laptop computer. In certain other embodiments, computer system **1700** may comprise a mobile device, such as a smart phone. In certain additional embodiments, computer system **1700** may comprise an embedded system.

Turning ahead in the drawings, FIG. **19** illustrates a flow chart for a method **1900** of providing a device for selectively harvesting crops on a plant in accordance with the present disclosure. Method **1900** is merely exemplary and is not limited to the embodiments presented herein. Method **1900** can be employed in many different embodiments or examples not specifically depicted or described herein. In some embodiments, the procedures, the processes, and/or the activities of method **1900** can be performed in the order presented. In other embodiments, the procedures, the processes, and/or the activities of method **1900** can be performed in any suitable order. In still other embodiments, one or more of the procedures, the processes, and/or the activities of method **1900** can be combined or skipped. In some embodiments, the plant can be a strawberry plant and each of the crops can be a strawberry. The plant can be similar or identical to plant **1510** (FIG. **15**). Each of the crops can be similar or identical to strawberry **535** (FIG. **5**). In other embodiments, the plant can be another suitable plant.

Referring to FIG. **19**, method **1900** can include a block **1901** of providing a picking apparatus. In many embodiments, the picking apparatus can be similar or identical to picking apparatus **110** (FIGS. **1-3**). In a number of embodiments, the picking apparatus can be rotatable around a central axis. The central axis can be similar or identical to central axis **311** (FIG. **3**). In various embodiments, the central axis can be parallel to a growing bed of the plant. The growing bed can be similar or identical to growing bed **1501** (FIG. **15**). In several embodiments, the picking apparatus can include a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops. The individual crop can be similar or identical to crop **535**, or another suitable crop. The grippers can be similar or identical to grippers **312-315** (FIG. **3**). In some embodiments, the plurality of grippers can include four grippers. For example, the picking apparatus can include, four, fix, six, seven, eight, or more grippers. In other embodiments, the plurality of grippers can include fewer than four grippers.

In a number of embodiments, each of the plurality of grippers can be adjustable between an open position and a closed position. The open position can be similar or identical to the open position shown in FIG. **4**. The close position can be similar or identical to the closed position shown in FIG. **5**. In various embodiments, each of the plurality of grippers can be configured in the open position to open around the individual crop. In several embodiments, each of the plurality of grippers can be configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis.

In some embodiments, each of the plurality of grippers can be configured to securely hold the individual crop in the closed position across different sizes of the individual crop. In many embodiments, each of the plurality of grippers can include a first claw piece and a second claw piece. The first claw piece can be similar or identical to first claw piece **410** (FIGS. **4-5**). The second claw piece can be similar or identical to second claw piece **420** (FIGS. **4-5**). In many embodiments, the first claw piece and/or the second claw piece can each include a metal frame at least partially covered with silicone rubber.

In a number of embodiments, for each of the plurality of grippers, the first claw piece can include a first wedged-shaped tip and/or the second claw piece can include a second wedge-shaped tip. The first wedge-shaped tip can be similar or identical to first tip **413** (FIGS. **4-5**), and/or the second wedge-shaped tip can be similar or identical to second tip **423** (FIGS. **4-5**). In a number of embodiments, when each of the plurality of grippers is in the open position (such as shown in FIG. **4**), the first wedged-shaped tip and the second wedge-shaped tip are adjustable to fit around the individual crop and to separate the individual crop from one or more proximate crops.

In various embodiments, each of the plurality of grippers can further include a first flexible strip attached to the first claw piece and/or a second flexible strip attached to the second claw piece. The first flexible strip can be similar or identical to first strip **414** (FIGS. **4-5**), and/or the second flexible strip can be similar or identical to second strip **424** (FIGS. **4-5**). In several embodiments, when the gripper is adjusted to the closed position around the individual crop, the first flexible strip and the second flexible strip can be configured to bend to allow for different sizes of the individual crop.

Method **1900** next can include a block **1902** of providing a carriage assembly. In a number of embodiments, the carriage assembly can be similar or identical to carriage assembly **140** (FIGS. **1-2**, **6-8**). In some embodiments, the carriage assembly can include a first rotational mechanism. In many embodiments, the first rotational mechanism can be similar or identical to rotational shaft **655** (FIGS. **6-7**), motor **654** (FIGS. **6-8**), gear **854** (FIG. **8**), and/or gear **855** (FIG. **8**). In several embodiments, the picking apparatus can be configured to be coupled to the first rotational mechanism. In some embodiments, the first rotational mechanism can be configured to rotate the picking apparatus around the central axis in a rotational path with respect to the carriage assembly.

In some embodiments, the carriage assembly can further include a first cam surrounding the first rotational mechanism. The first cam can be similar or identical to stationary cam **669** (FIGS. **6**, **8-11**). In a number of embodiments, the carriage assembly can further include an actuator. The actuator can be similar or identical to actuator **661** (FIGS. **6-11**), motor **653** (FIGS. **6-8**), and/or actuation cam **660** (FIGS. **6-7**, **9-11**). In some embodiments, the first cam can be configured to hold the plurality of grippers in the closed position for a first portion of the rotational path and to allow the plurality of grippers to open to the open position for a second portion of the rotational path from a release position to a picking position. The first portion of the rotational path can be similar or identical to first portion **964** (FIGS. **9-11**), and/or the second portion of the rotational path can be similar or identical to second portion **965** (FIGS. **9-11**). The release position can be similar or identical to release position **967** (FIGS. **9-11**), and/or the picking position can be similar or identical to picking position **966** (FIGS. **9-11**). In a number of embodiments, the first cam can be configured to stop rotation of the picking apparatus when each of the plurality of grippers is rotated to the picking position on the second portion of the rotational path. In various embodiments, the actuator can be configured to adjust an opening width of a picking gripper of the plurality of grippers at the picking position to isolate the individual crop and to close the gripper to securely hold the individual crop. The picking gripper can be similar or identical to gripper **312** at picking position **966** as shown in FIGS. **10-11**. The first cam can be configured such that, as each of the plurality of grippers rotates to the release position of the rotational path, each of the plurality of grippers can be configured to open to the open position and release the individual crop in a collection device.

Method **1900** next can optionally include a block **1903** of providing a carrier assembly. The carrier assembly can be similar or identical to carrier assembly **170** (FIGS. **1-2**, **12-13**). In some embodiments, the carrier assembly can include a second rotational mechanism. The second rotational mechanism can be similar or identical to mounting bearing **1274** (FIGS. **12-13**). In various embodiments, the second rotational mechanism can be configured to rotate the carrier assembly around the second rotational mechanism such that the picking apparatus can be rotated around the plant when the second rotational mechanism is centered above the plant.

Method **1900** next can include a block **1904** of providing one or more imaging sensors. In a number of embodiments, the one or more imaging sensors can be similar or identical to imaging sensor **1290** (FIGS. **12-13**) and/or imaging sensor **1291** (FIGS. **12-13**).

Method **1900** next can include a block **1905** of providing a processing unit. The processing unit can be similar or identical to processing unit **1273** (FIGS. **12-13**). In a number of embodiments, the processing unit can be configured to receive information from the one or more imaging sensors to determine the location of the crops to be harvested.

Method **1900** next can optionally include a block **1906** of providing a foliage displacement mechanism. In many embodiments, the foliage displacement mechanism can be similar or identical to foliage displacement mechanism **1400** (FIGS. **14-16**). In several embodiments, the foliage displacement mechanism can be configured to move foliage of the plant and expose at least a portion of the crops to the one or more image sensors. The foliage can be similar or identical to foliage **1512** (FIG. **15**). In some embodiments, the foliage displacement mechanism can include a back surface. The back surface can be similar or identical to back surface **1410** (FIG. **14**). In many embodiments, the back surface can be configured to extend normal to a growing bed of the plant. In various embodiments, the foliage displacement mechanism can include a base. The base can be similar or identical to base **1420** (FIG. **14**). In several embodiments, the base can be configured to extend parallel to the growing bed from the back surface toward the plant. In some embodiments, the foliage displacement mechanism can include a curved surface. The curved surface can be similar or identical to surface **1440** (FIG. **14**). In a number of embodiments, the curved surface can extend from the base upward to the back surface. In many embodiments, the foliage displacement mechanism can include a channel. The channel can be similar or identical to channel **1450** (FIG. **14**). In some embodiments, the channel can bisect a front portion of the base and extend upward through the curved surface. In several embodiments, the channel can be configured to surround a center of the plant when the foliage displacement mechanism is moved toward the plant. The center of the plant can be similar or identical to center **1513**. In some embodiments, the foliage displacement mechanism can be configured, when moved toward the plant, to move the foliage upward and toward the center of the plant.

Although automated selective harvesting of crops has been described with reference to specific embodiments, it will be understood by those skilled in the art that various changes may be made without departing from the spirit or scope of the disclosure. Accordingly, the disclosure of embodiments is intended to be illustrative of the scope of the disclosure and is not intended to be limiting. It is intended that the scope of the disclosure shall be limited only to the extent required by the appended claims. For example, to one of ordinary skill in the art, it will be readily apparent that any element of FIGS. **1-19** may be modified, and that the foregoing discussion of certain of these embodiments does not necessarily represent a complete description of all possible embodiments. For example, one or more of the procedures, processes, or activities of FIG. **19** may include different procedures, processes, and/or activities and be performed by many different modules, in many different orders.

All elements claimed in any particular claim are essential to the embodiment claimed in that particular claim. Consequently, replacement of one or more claimed elements constitutes reconstruction and not repair. Additionally, benefits, other advantages, and solutions to problems have been described with regard to specific embodiments. The benefits, advantages, solutions to problems, and any element or elements that may cause any benefit, advantage, or solution to occur or become more pronounced, however, are not to be construed as critical, required, or essential features or elements of any or all of the claims, unless such benefits, advantages, solutions, or elements are stated in such claim.

Moreover, embodiments and limitations disclosed herein are not dedicated to the public under the doctrine of dedication if the embodiments and/or limitations: (1) are not expressly claimed in the claims; and (2) are or are potentially equivalents of express elements and/or limitations in the claims under the doctrine of equivalents.

What is claimed is:

1. A device for selectively harvesting crops on a plant, the device comprising:

a picking apparatus, the picking apparatus being rotatable around a central axis, the picking apparatus comprising:

a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops;

a carriage assembly comprising a first rotational mechanism; and

a carrier assembly comprising a second rotational mechanism,

wherein:

each of the plurality of grippers are adjustable between an open position and a closed position;

each of the plurality of grippers are configured in the open position to open around the individual crop;

each of the plurality of grippers are configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis;

the picking apparatus is configured to be coupled to the first rotational mechanism;

the first rotational mechanism is configured to rotate the picking apparatus around the central axis in a rotational path with respect to the carriage assembly;

the carriage assembly is coupled to the carrier assembly; and

the second rotational mechanism is configured to rotate the carrier assembly around the second rotational mechanism such that the picking apparatus is rotated around the plant when the second rotational mechanism is centered above the plant.

2. The device of claim **1**, wherein:

the plurality of grippers comprises four grippers.

3. The device of claim **1**, wherein:

the plant is a strawberry plant; and

each of the crops is a strawberry.

4. The device of claim **1**, wherein:

each of the plurality of grippers are configured to securely hold the individual crop in the closed position across different sizes of the individual crop.

5. The device of claim **1**, wherein:

each of the plurality of grippers comprises a first claw piece and a second claw piece.

6. The device of claim **5**, wherein,

for each of the plurality of grippers:

the first claw piece comprises a first wedged-shaped tip;

the second claw piece comprises a second wedge-shaped tip; and

when each of the plurality of grippers is in the open position, the first wedged-shaped tip and the second wedge-shaped tip are adjustable to fit around the individual crop and to separate the individual crop from one or more proximate crops.

7. The device of claim **5**, wherein:

each of the plurality of grippers further comprises:

a first flexible strip attached to the first claw piece; and

a second flexible strip attached to the second claw piece; and

when each of the plurality of grippers is adjusted to the closed position around the individual crop, the first flexible strip and the second flexible strip are configured to bend to allow for different sizes of the individual crop.

8. The device of claim **5**, wherein:

the first claw piece and the second claw piece each comprise a metal frame at least partially covered with silicone rubber.

9. The device of claim **1** further comprising:

one or more imaging sensors; and

a processing unit,

wherein:

the processing unit is configured to receive information from the one or more imaging sensors to determine a location of the crops to be harvested.

10. The device of claim **9** further comprising:

a foliage displacement mechanism configured to move foliage of the plant and expose at least a portion of the crops to the one or more imaging sensors.

11. The device of claim **10**, wherein:

the foliage displacement mechanism comprises:

a back surface configured to extend normal to a growing bed of the plant;

a base configured to extend parallel to the growing bed from the back surface toward the plant;

a curved surface extending from the base upward to the back surface; and

a channel bisecting a front portion of the base and extending upward through the curved surface, the channel being configured to surround a center of the plant when the foliage displacement mechanism is moved toward the plant,

wherein:

the foliage displacement mechanism is configured, when moved toward the plant, to move the foliage upward and toward the center of the plant.

12. The device of claim **1**, wherein:

the carriage assembly further comprising:

a first cam surrounding the first rotational mechanism; and

an actuator; and

the central axis is parallel to a growing bed of the plant;

the first cam is configured to hold the plurality of grippers in the closed position for a first portion of the rotational path and to allow the plurality of grippers to open to the open position for a second portion of the rotational path from a release position to a picking position;

the first cam is configured to stop rotation of the picking apparatus when each of the plurality of grippers is rotated to the picking position on the second portion of the rotational path;

the actuator is configured to adjust an opening width of a picking gripper of the plurality of grippers at the picking position to isolate the individual crop and to close the picking gripper to securely hold the individual crop; and

the first cam is configured such that, as each of the plurality of grippers rotates to the release position of the rotational path, each of the plurality of grippers is configured to open to the open position and release the individual crop in a collection device.

13. The device of claim **1**, wherein:

when the second rotational mechanism is centered above the plant and one of the plurality of grippers is in the open position, the device is configured to lower the one of the plurality of grippers to a growing bed of the plant to pick the individual crop.

14. A method of providing a device for selectively harvesting crops on a plant, the method comprising:

providing a picking apparatus, the picking apparatus being rotatable around a central axis, the picking apparatus comprising a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops;

providing a carriage assembly comprising a first rotational mechanism; and

providing a carrier assembly comprising a second rotational mechanism,

wherein:

the picking apparatus is configured to be coupled to the first rotational mechanism;

the first rotational mechanism is configured to rotate the picking apparatus around the central axis in a rotational path with respect to the carriage assembly;

each of the plurality of grippers are adjustable between an open position and a closed position;

each of the plurality of grippers are configured in the open position to open around the individual crop;

each of the plurality of grippers are configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis:

the carriage assembly is coupled to the carrier assembly; and

the second rotational mechanism is configured to rotate the carrier assembly around the second rotational mechanism such that the picking apparatus is rotated around the plant when the second rotational mechanism is centered above the plant.

15. The method of claim **14**, wherein:

the plurality of grippers comprises four grippers.

16. The method of claim **14**, wherein:

the plant is a strawberry plant; and

each of the crops is a strawberry.

17. The method of claim **14**, wherein:

each of the plurality of grippers are configured to securely hold the individual crop in the closed position across different sizes of the individual crop.

18. The method of claim **14**, wherein:

each of the plurality of grippers comprises a first claw piece and a second claw piece.

19. The method of claim **18**, wherein:

for each of the plurality of grippers:

the first claw piece comprises a first wedged-shaped tip;

the second claw piece comprises a second wedge-shaped tip; and

when each of the plurality of grippers is in the open position, the first wedged-shaped tip and the second wedge-shaped tip are adjustable to fit around the individual crop and to separate the individual crop from one or more proximate crops.

20. The method of claim **18**, wherein:

each of the plurality of grippers further comprises:

a first flexible strip attached to the first claw piece; and

a second flexible strip attached to the second claw piece; and

when each of the plurality of grippers is adjusted to the closed position around the individual crop, the first flexible strip and the second flexible strip are configured to bend to allow for different sizes of the individual crop.

21. The method of claim **18**, wherein:

the first claw piece and the second claw piece each comprise a metal frame at least partially covered with silicone rubber.

22. The method of claim **14** further comprising:

providing one or more imaging sensors; and

providing a processing unit,

wherein:

the processing unit is configured to receive information from the one or more imaging sensors to determine a location of the crops to be harvested.

23. The method of claim **22** further comprising:

providing a foliage displacement mechanism configured to move foliage of the plant and expose at least a portion of the crops to the one or more imaging sensors.

24. The method of claim **23**, wherein:

the foliage displacement mechanism comprises:

a back surface configured to extend normal to a growing bed of the plant;

a base configured to extend parallel to the growing bed from the back surface toward the plant;

a curved surface extending from the base upward to the back surface; and

a channel bisecting a front portion of the base and extending upward through the curved surface, the channel being configured to surround a center of the plant when the foliage displacement mechanism is moved toward the plant,

wherein:

the foliage displacement mechanism is configured, when moved toward the plant, to move the foliage upward and toward the center of the plant.

25. A method of providing a device for selectively harvesting crops on a plant, the method comprising:

providing a picking apparatus, the picking apparatus being rotatable around a central axis, the picking apparatus comprising a plurality of grippers each spaced apart and extending radially from the central axis, and each configured to pick a different individual one of the crops; and

providing a carriage assembly comprising a first rotational mechanism,

wherein:

the picking apparatus is configured to be coupled to the first rotational mechanism;

the first rotational mechanism is configured to rotate the picking apparatus around the central axis in a rotational path with respect to the carriage assembly;

each of the plurality of grippers are adjustable between an open position and a closed position;

each of the plurality of grippers are configured in the open position to open around the individual crop;

each of the plurality of grippers are configured in the closed position to securely hold the individual crop when the picking apparatus is rotated around the central axis;

the carriage assembly further comprises:

a first cam surrounding the first rotational mechanism; and

an actuator; and

the central axis is parallel to a growing bed of the plant;

the first cam is configured to hold the plurality of grippers in the closed position for a first portion of the rotational path and to allow the plurality of grippers to open to the open position for a second portion of the rotational path from a release position to a picking position;

the first cam is configured to stop rotation of the picking apparatus when each of the plurality of grippers is rotated to the picking position on the second portion of the rotational path;

the actuator is configured to adjust an opening width of a picking gripper of the plurality of grippers at the picking position to isolate the individual crop and to close the picking gripper to securely hold the individual crop; and

the first cam is configured such that, as each of the plurality of grippers rotates to the release position of the rotational path, each of the plurality of grippers is configured to open to the open position and release the individual crop in a collection device.

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